

Institute of Metals

The Autumn Annual Meeting of the Institute of Metals was held at Southampton on September 9—12. A Civic Welcome was accorded the members by the Mayor, Councillor Hector Young, to which the President of the Institute, Dr. Richard Seligman, returned thanks on behalf of the Council and Members. Addressing the members, the President expressed pleasure in seeing so many overseas members present. When business formalities were over the technical session commenced for the presentation of papers, from which the following are extracts.

GAS REMOVAL AND GRAIN REFINEMENT OF ALUMINIUM ALLOYS.

By W. ROSENHAIN, D.Sc., F.Inst., Met., F.R.S., Past-President; J. D. GROGAN, B.A., and T. H. SCHOFIELD, M.S. (From the National Physical Laboratory).

THIS paper describes an investigation carried out for the Department of Scientific and Industrial Research by the Alloys Sub-Committee of the Aeronautical Research Committee, who have granted permission for the present publication. The investigation constitutes a continuation of the systematic study of aluminium and its alloys, which has long been in progress in the Metallurgy Department of the National Physical Laboratory.

Recent developments in the treatment of aluminium and some of its alloys for the removal of gas were stimulated first by the work of Archbutt on "pre-solidification" and by Rosenhain's method of passing nitrogen through the molten metal. This has since been extended by Tullis, who has examined the behaviour of chlorine and developed the use of boron trichloride.

The remarkable effects of boron trichloride in bringing about removal of gas and grain refinement, as described by Tullis, suggested to the present authors that similar effects might be obtained more conveniently by the use of other substances, and carbon tetrachloride, silicon tetrachloride, titanium tetrachloride, tin tetrachloride, aluminium chloride, ferric chloride, and tetrachlor-ethane were chosen for investigation.

All the materials employed proved efficacious in removal of gas from the metal. Even tetrachlor-ethane, which contains a considerable percentage of hydrogen, is little, if at all, inferior to the other reagents in this respect, although in this case all the castings show slight signs of residual gas. Concerning the relative efficiency of the various reagents, there is some doubt, owing to the wide limit of experimental error produced by the small quantities of metal employed. Tin tetrachloride and ferric chloride contaminate the metal with tin and iron, and, by altering the density, prevent

TABLE I.—DENSITY OF HALF-SECTIONS OF 3 IN. DIAMETER SILICON ALUMINIUM CASTINGS.

Material Used.	Quantity Used.				
	0 Units	2 Units	4 Units	8 Units	16 Units
Carbon tetrachloride ..	2.579	2.596	2.605	2.625	2.671
Silicon tetrachloride ...	—	2.589	2.592	2.658	2.666
Titanium tetrachloride ..	2.566	2.643	2.645	2.642	—
Tin tetrachloride	2.574	—	2.589	2.605	2.680
Aluminium chloride ..	2.569	—	2.607	2.662	—
Ferric chloride	2.569	—	2.589	—	2.652
Tetrachlor-ethane	2.574	—	2.589	2.663	2.657

that property from being used as an accurate measure of soundness. Silicon tetrachloride, carbon tetrachloride, tetrachlor-ethane, and aluminium chloride give much the same density (2.66) after treatment with 16 units in the case of carbon tetrachloride and 8 in the case of the other three. The influence of titanium tetrachloride was investigated on metal from another source and gave sound castings, although of lower density, after treatment with 4 units. While the evidence available is not sufficient to justify a claim that titanium tetrachloride is to this extent

more efficient than the other reagents, it has been shown on large melts of other alloys that this quantity is sufficient regularly to remove gas from the metal. The density figures obtained are given in Table I.

As no satisfactory reagent is as yet available to disclose the macro-structure of silicon-aluminium alloys, the accurate determination of grain-size in this case is difficult. The distribution of the dendrites of primary aluminium and the orientation of needles in the eutectic afford an indication, which, however, is seriously influenced by the change in micro-structure described above. Careful examination did not indicate that any alteration of grain-size is produced by treatment with carbon, or silicon tetrachlorides, tetrachlor-ethane or aluminium, or ferric chlorides. Treatment with titanium tetrachloride, and to a lesser extent with tin tetrachloride, produces a definite reduction in grain-size.

As unalloyed aluminium when sand-cast develops a relatively coarse crystal structure, which is easily disclosed by etching, it was employed in the investigation into the influence of these reagents on grain-size, and the results obtained confirm the observations made on the silicon-aluminium alloy. Carbon tetrachloride, silicon tetrachloride, ferric chloride, and aluminium chloride do not alter the grain-size. Tin tetrachloride produces a small but definite reduction, and titanium tetrachloride a marked reduction.

It appeared from these experiments that titanium itself is the grain-refining agent. Consequently, material treated with titanium tetrachloride should give the same fine structure after remelting, provided that the titanium is not eliminated during melting. The same fine structure is obtained, even when the metal has been kept molten for 30 mins. at a temperature of 740°—780° C. before re-casting. This result is confirmed by adding titanium in the form of alloy prepared by the "Thermit" process. By this means metal containing 0.12% of titanium was prepared and cast. The crystal size of this metal is small, comparable with that of metal treated with titanium tetrachloride. On the other hand, the metal is low in density, which is 2.617, compared with 2.670 of the sand-cast virgin aluminium, and it also contains cavities visible to the naked eye. It appears, therefore, that titanium does not prevent the absorption of gases by molten aluminium.

The quantity of titanium found in aluminium and silicon-aluminium after treatment with titanium tetrachloride has been found to vary from a trace upwards, but never approaches the quantity of titanium employed. In alloys containing magnesium, however, considerably greater quantities of titanium are absorbed, and selective elimination of magnesium occurs.

As titanium tetrachloride had proved to be efficient both in the removal of gas and in reducing grain size, it was decided to investigate the manner in which these refinements would influence the mechanical and "working" properties of a commercial alloy, and for this purpose "Y" alloy was selected as one which is employed in both the cast and wrought states. The influence of titanium tetrachloride in removing gas from this alloy was examined in the usual manner, and the results indicated that this reagent provides a method of producing castings of high quality and markedly improves the "working" properties of the metal.

Dr. W. Rosenhain, in introducing this paper, said it was written some nine months ago, and a further step had been made. Instead of introducing the volatile chloride as such, or by itself by mere volatilisation under heat and pressure into the metal, as we describe in this paper, we have now found it possible to introduce a stream of dry nitrogen gas, which is passed over it and is then carried through the metal by this stream of nitrogen. This has not yet been tried on a very large range of alloys, but, as far as it has been tried, it appears to work very conveniently, and offers a very easy clean way of carrying out this process.

Referring to an omission from the paper, Dr. Rosenhain said that anything which contains water vapour, or even hydrogen components, is likely to be decomposed and yield hydrogen in a form which is quickly absorbed by aluminium. For example, an ordinary gas or oil flame allowed to play on the surface of the metal will saturate the metal with hydrogen, and these de-gassing processes are entirely unsuccessful if they are carried out in conditions under which a gas flame under pressure has any access.

Mr. D. R. Tullis (Glasgow), opening the discussion, said the subject had occupied his attention for many years. The process of removing gases, he said, must be absolutely correct to obtain complete freedom from residual gases. The least expensive gas to employ he contended is pure chlorine gas, but this presents a danger to operators. The use of chlorine-gas compounds is safer, as, in the presence of moist air, these generally decompose to hydrogen chloride and metallic or non-metallic hydroxide. The method of employing a grain refining element combined with chlorine is one which was, he said, developed in his own laboratory. It has the advantage of combining the two operations in a single process. The most effective substances known at present to produce this combined result are the chlorides of boron, titanium, and vanadium. In a given alloy any one may be more effective than either of the other two. In some cases a combination of any two may be more effective than one singly, it being necessary that the same relative amount is applied in each case. Mr. Tullis expressed gratification that the results obtained by him in respect to grain refinement were so well confirmed in the paper, and, in conclusion, thanked Dr. Rosenhain for the keen interest shown in work carried out in his laboratory.

Mr. G. Mortimer (London), who is Chairman of a Research Committee engaged on this problem, stated that he had tried Dr. Rosenhain's titanium-tetrachloride method on quite a large foundry scale with very successful results indeed, provided that one adopts quite a definite temperature at which to apply the gas, and his experience indicates that temperature varies with each different alloy. The formation of dense white fumes has been a difficulty, and another method has been adopted more suited to practical requirements; dried asbestos-wool waste is soaked with the required quantity of it and put at the bottom of the melt. It is a very easy process.

Dr. Leslie Aitchison (Birmingham) expressed his conviction that this process is actually one which does achieve the object that it sets out to achieve; that is to say, it does remove pretty nearly all the harmful gases from aluminium; and the whole crux of the matter now is for Dr. Rosenhain to spend some time in considering the suitable method of applying it in practice. There are so many difficulties in practice. Mr. Mortimer has hinted at one of them. This process, if it can be applied in general practice, is a very valuable process.

Dr. M. H. Haas (Germany) agreed with Dr. Aitchison, that the first question is how to apply this process in a commercial way. The tetrachloride process is very interesting and successful, but it will be very difficult to give it practical application.

In replying, Dr. Rosenhain agreed with Dr. Haas and Mr. Mortimer that the methods that have been used for

introducing these gases are primitive laboratory methods, just as the method of using asbestos soaked in tetrachloride may be described as a primitive works method. The real solution of the problem probably lies in pouring the melting chloride into a vessel, or actually melting it in that vessel, or blowing the gas bearing the volatile chloride in it through the metal. That, of course, is a mechanical method, and satisfactory when carried out on a large scale; it avoids the bogey of fumes in the foundry. If you do the thing through a converter, you can quite easily catch the effluent gases in that converter and pump them away. Dr. Rosenhain did not agree with Dr. Haas that chlorine really is as good as these chlorides.

Professor Daniel Hanson (Birmingham) who has been working on a similar problem for the last 12 months, confirmed a great deal of what was said in this paper. The treatment of aluminium alloys by various gases, particularly chlorides, can be a very effective way of removing gas. Difficulties arise in applying the method to large quantities. Small quantities can be treated and a very effective removal obtained in a relatively short time, but with large quantities the time required is rather great, and sometimes it is quite impossible, with any of the known methods, to get enough gas in before the metal has got too cold. If the process is to be successful, he continued, careful consideration will need to be given to methods of putting the gas in sufficiently rapidly and in sufficient quantity to effect the gas removal. Even in small quantities, say 20 or 30 lb., it will often take 15 to 20 minutes to get a really effective removal of gas, although some improvement may result with a smaller time of treatment, and when it comes to larger quantities the time is sometimes much greater. One trouble with users is that they do not pass the gas in quickly enough.

Mr. J. D. Grogan thanked all who had spoken on his paper, and stated that replies to most of the points raised will be made in writing. In commenting on the question of dry nitrogen, he considered this point was very much over-emphasized; ordinary nitrogen is dry enough, but it has got oxygen in it, that is the main trouble in passing it into molten aluminium, and particularly when magnesium is present in the alloys, as oxide inclusions do as much harm as the gas. A great source of danger is the type of furnace used, and after commenting on furnaces, Mr. Grogan said that no amount of drying the nitrogen will do any good if the melting conditions are not suitable.

PRESSURE DIE-CAST ALUMINIUM ALLOY TEST PIECES.

By J. D. GROGAN, B.A.

THIS paper refers to an investigation of mechanical strength of certain aluminium alloys when pressure-cast in the form of small tensile test pieces, and is complementary to a previous paper presented to the Institute by Archbutt, Grogan, and Jenkin, in which the properties and production of gravity-cast test pieces of some alloys of aluminium were described. These alloys, when molten, are very corrosive, so that the choice of material for container to hold them under pressure was somewhat difficult. In addition to experimenting with a number of metals to determine which seemed likely to be suitable in this respect, the investigation involved the design and production of a pressure-cast machine capable of giving control of casting conditions to fulfil the requirements of the investigation. In selecting a material for the construction of a vessel to hold molten aluminium alloy under pressure, it was necessary that it should be strong enough, at the rather high temperatures employed, to withstand the pressure to be applied, and also capable of resisting the attack of molten aluminium alloys as completely as possible. The materials and particulars respecting them which were selected for test are

given in Table I. Tests to which these metals were subjected indicated that none of the materials were completely resistant to attack by molten 8% copper-aluminium alloy. The results obtained are shown in Table II.

TABLE I.—COMPOSITION OF MATERIALS EMPLOYED.

Material.	Ni.	Cr.	Fe.	Al.	Si.	C.	Mn.	W.
Nickel chromium.	80	20	—	—	—	—	—	—
Cronite	59.8	14.4	22.6	—	0.5	0.66	0.99	—
Calite	19.9	27.2	47.8	3.7	0.4	1.8	—	—
"Era" steel	6.75	18.8	65.6	—	1.35	0.29	3.11	4.05

The specified composition of chrome-vanadium was carbon 0.4, phosphorus and sulphur not exceeding 0.06, chromium 1.5, and vanadium 0.35%. The case iron was of grey cylinder iron quality.

TABLE II.—RATE OF ATTACK BY MOLTEN 8% COPPER-ALUMINIUM ALLOY OF SELECTED MATERIALS.

Material.	Percentage Reduction in Dia. after Immersion for :	
	2½ Hours.	13½ Hours.
Nickel-chromium alloy	50.0	—
Cronite	7.5	31.8
Calite	3.7	22.2
"Era" steel	5.2	14.3
Chrome-vanadium steel	3.3	10.0*
Grey cast-iron	2.8	8.8

* Mean value. The bar became tapered.

Grey cast iron withstood the test best. Chrome-vanadium steel and "Era" steel were somewhat inferior, and Calite steel worse. Cronite was somewhat badly attacked, and the nickel-chromium alloy very rapidly attacked. The casting skin on the sand-cast bars, which affords very appreciable protection, appears to be penetrated on prolonged immersion and then no longer affords protection.

The chrome-vanadium steel employed in these tests had been recommended as suitable for the melting vessel to be employed in pressure casting, and as nothing superior to it was disclosed in these tests, it was chosen in this investigation for the purpose, and gave excellent service.

Although it is usual in the production of pressure castings of alloys at low melting point to apply pressure by means of a metal plunger, this method demands a material which is not attacked by the molten metal, and no sufficiently resistant material being available it was decided to employ air pressure. For this purpose a supply of air at 80 lb. pressure was available, and was employed throughout the investigation.

Many difficulties were encountered as a result of air being carried into the mould with the entering metal. To overcome this difficulty, the apparatus was designed to enable the metal to be brought up gently to the gate of the mould by gravity and then forced in by pressure. The test-pieces selected had dimensions of the small test-piece described on the report on "Gravity Die-castings," and were cast to shape ready for testing, without the employment of any machining other than the removal of runner and riser. The diameter of the strength portion was 0.282 in. The moulds in which the test-pieces were made were preheated and used alternately, one being preheated while the other was in use, to ensure the mould temperature being maintained at about 500° C. The metal temperature employed was rather under 750° C. As a rule, these castings were made at the average rate of one every 2 mins. When the group was finished the mould temperature had fallen to about 350° C., and the solidification of metal in the orifice of the vessel was becoming sufficiently serious to hinder production. The mould was then reheated, and the other one employed.

Preliminary results from a number of castings produced in Y-alloy indicated that while some were extracted sound others were found to be cracked when the mould was opened. The adoption of a more deliberate procedure in handling the mould increased the yield of satisfactory test-pieces without appreciably decreasing the rate of progress. The average yield became about 50%, the results obtained were variable and generally not good. It appeared that dross was entering the mould with the metal. Procedure was adopted to prevent this as far as possible, and the position of the mould relative to the vessel was altered so that the gate was situated at the bottom of the orifice when in the casting position. This resulted in considerable improvement.

With copper-silicon alloy the yield of satisfactory castings was increased, and the contamination due to dross inclusion was much less marked. Tests were made with the 12% silicon-aluminium alloy, but owing to the failure of the casting vessel during the first run of this alloy, little information is available as to its yield. Comparisons were made of the mechanical properties by pressure-cast and gravity-cast test-pieces, and it was found that the mechanical properties of the best castings obtained under pressure were superior to those of the best gravity castings produced during this investigation, and considerably superior to those produced in the previous paper referred to. On pressure castings the best figures obtained for elongation averaged 4.2%, while for gravity castings the average was 3.5%. Similarly, the best tensile figures for pressure castings given as a mean figure 12.0 tons per square inch to an average of 11.2 tons per square inch for gravity castings. This superiority is apparent also after heat-treatment. It had been suspected that gases would become dissolved in the molten metal when subjected to pressure, and would cause unsoundness in the castings. This appears not to be the case.

All the time that metal remained molten in the casting vessel iron was slowly absorbed from the chrome-vanadium steel of which the vessel was made. Analysis showed the presence of iron in quantities up to 2% in castings. The alloys, therefore, were always gradually changing in composition from that originally intended.

Mr. A. H. Nicholson, commencing the discussion on this paper, said it should dispel the idea still prevalent in some quarters that aluminium pressure die castings are without strength, and therefore unsuited to engineering uses. The fact is, of course, that they are being increasingly used, and often replace machined gravity castings. The results the authors obtain from the test bars are surprisingly good, considering the slow speed of casting and the low casting pressure used. Slow speed of casting causes iron absorption and porosity results from low pressure.

Iron absorption can be decidedly difficult in pressure work. Of all the material available for the pressure vessel grey cast iron is the least attacked by aluminium; but, without experience, one hesitates to apply, say, 600 lb. air pressure to a red-hot cast-iron vessel. Nevertheless, cast iron is generally used and nearly always fails by cracking; not bursting, as one would expect.

Given then a cast-iron pressure vessel, the absorption of iron may be still further reduced by working the metal through it quickly and using alloys which do not readily absorb iron, or, better still, alloys whose composition includes iron, allowances being made for the iron they will pick up in the casting process.

Porosity is always present more or less in pressure die castings. High-casting pressures undoubtedly reduce it, and with this object 600 lb. is a common pressure to-day. Had the authors employed a higher pressure than 80 lb. their results should have been even better than those obtained. It would be interesting to know whether the very fine grain of pressure castings accelerates heat-treatment.

Mr. G. Mortimer congratulated Mr. Grogan on his weary pilgrimage through all the troubles which founders have to go through every day in producing pressure die castings. Professor Hanson, he said, sounded a note of warning in his autumn lecture when he said there were no melting troubles associated with magnesium, because magnesium did not attack iron. Aluminium does, and there is really a fortune awaiting anyone who can produce a really satisfactory melting handling material for aluminium. In regard to pressure, applied to a casting cast by gravity to bring about feeding, higher results must necessarily follow. An apparatus to do that was set up in his foundry, and the experiment was carried out for some months. It was, however, a failure progressively as the pressure went up.

Mr. E. V. Pannell, who followed in the discussion, said the two main lines of die or pressure casting come under the heading of the mechanical and metallurgical elements. It is a little doubtful whether the very painstaking investigation which we have here presented has thoroughly eliminated the multifarious factors pertaining to the mechanical side of pressure casting before attacking the metallurgical phase. Among these varying factors the matter of pressure has already been raised. The pressure used in modern light alloy casting practice is of the order of 400 to 600 lb., and a very great difference will be found between metal which is gently pushed into a die and that which is deliberately shot in. Furthermore, the size of gate is one of the most important factors in the provision of a satisfactory cast.

Commenting further, Mr. Pannell said that it was a little surprising to find that the aluminium-copper alloys gave unsatisfactory results, in view of the many thousands of tons of such alloys which have been pressure cast. An average tensile strength of 15 tons gives an average elongation of 3% in 2 in., is quite standard practice, and the castings are metallurgically homogeneous.

Mr. A. H. Munday referred to the paper as characterised by that transparent honesty which tells of failures experienced. Die-casters, he said, have difficulty in obtaining a material for the containers or goosenecks, or whatever other form the container takes, for holding the molten aluminium. He thought everything had been tried that had been suggested, but had fallen back upon good cast-iron, in common with all other experienced die-casters, or at least, pressure die-casters for aluminium.

In further comment, Mr. Munday referred to die-cast test pieces. Testing he said is very largely used for inspection, and he suggested the desirability of educating inspectors, designers and engineers, who are going over the material to the acceptance of a die-cast test piece, and that the Institute should influence public bodies, the B.E.S.A. and other bodies, which influence the framing of specifications, to the view that die-cast test pieces should be accepted to represent die-castings, because no other means can adequately represent a die-casting.

Dr. Rosenhain, as Chairman of the Die Casting Research Committee, discussed some aspects of this work which were raised. The suggestion that this work might be continued is dependent on offers and support. The question of low-pressure used was due to lack of funds necessary for installing the machinery to give pressures of 1,000 lbs. and more. The industry is quite ready to criticise the results which have been given them, but they have not been so ready to contribute to the cost of producing them. The same thing applies to the question of contact with commercial practice; if the die-casting industry had been a little more ready to give us assistance in information and experience which they had accumulated, Mr. Grogan would not have been obliged to follow that painful pilgrimage to which Mr. Mortimer referred. Mr. Rosenhain suggested that actually, to obtain good test results under a lower pressure is perhaps a more

difficult achievement than when you get over your difficulties by using these higher pressures. He agreed that the investigation of higher pressures was highly desirable.

THE ARTIFICIAL AGEING OF DURALUMIN AND SUPER-DURALUMIN.

By K. L. MEISSNER, Dr.-Ing.

THE author has previously carried out investigations on the effect of artificial ageing upon aluminium alloys, containing magnesium which had been previously age-hardened at room temperature. During recent years some magnesium-containing aluminium alloys of the Duralumin type (which comprises all aluminium alloys containing magnesium, and which can be age-hardened at room temperature after soaking at temperatures above 420° C. and cooling, preferably by quenching in water to room temperature) have been worked out, which, owing to their magnesium content, can be age-hardened at room temperature, though artificial hardening can be applied. The present investigation was undertaken with a view to determining the effect of artificial ageing from 50° to 200° C. upon two commercial Duralumin alloys, 681 B and 681 B1/3, and upon super-Duralumin having the following composition:—

Alloy	Cu.	Mg.	Mn.	Fe.	Si.	Al.
681 B.....	4.2	0.5	0.6	0.3	0.3	Balance
681 B 1/3	4.2	0.5	0.25	0.3	0.3	Balance
Super-Duralumin ..	4.40	0.54	0.61	0.25	0.79	Balance

The periods of tempering were generally 20 and 40 hours. The artificial ageing was applied in the first series after ageing at room temperature; in the second series, immediately after quenching from high temperatures (about 500° C.). No substantial difference was noted between the two series.

In a third series, test-pieces were artificially aged after having been age-hardened at room temperature and cold-rolled. In this series an interesting phenomenon could be observed at about 100° to 125° C., in that material was produced having high tensile strength and elongation, combined with a yield-point which was about 33 to 53% higher than obtained in the two other series investigated.

The effect of artificial ageing upon Duralumin consists, after an initial softening at lower temperatures, mainly in raising the yield-point, whilst the tensile strength is influenced only slightly. At the same time, the elongation, flexibility, and other cold-working properties are decreased very markedly, and as shown in previous work, the resistance against corrosion is also decreased.

In contrast to Duralumin, the tensile strength of super-Duralumin is markedly raised by artificial ageing, but the rise keeps behind that of the yield-point, relatively. The other properties are, in general, substantially the same as those for Duralumin.

THE OPEN-AIR CORROSION OF COPPER.

PART II.—THE MINERALOGICAL RELATIONSHIPS OF CORROSION PRODUCTS.

By W. H. J. VERNON, D.Sc., Ph.D., D.I.C. and L. WHITBY, M.Sc.

IN the first part of this paper, published in the "Journal of the Institute of Metals" in 1929, the open-air corrosion of copper was discussed with particular reference to the green patina that characterises the metal surface under many conditions of exposure. Analyses of products from copper structures of various ages in representative localities

revealed that the major constituent was usually basic copper sulphate. Although in a purely marine atmosphere basic copper chloride predominated, when urban and marine conditions coincided the amount of basic sulphate greatly exceeded that of basic chloride. The proportion of basic copper carbonate was in all cases low. The data have since been re-examined, primarily with the view to ascertaining whether, under any conditions, definite formulae could be ascribed to these constituents. It was suggested to the authors by Professor G. T. Morgan that, in the light of the theory of co-ordination, the predominating basic copper sulphate would probably have a formula analogous to that of the mineral atacamite, $(\text{Cu}\{(\text{HO})_2\text{Cu}\}_3\text{Cl}_2)$. As applied to the older products, this prediction has proved remarkably accurate.

As a result of their investigations, the authors conclude that the principal constituents of the open-air corrosion products of copper, after prolonged exposure, tend to assume the chemical compositions of the corresponding minerals.

In the limit, basic copper sulphate, which is the major constituent under most conditions, coincides in composition with brochantite, $\text{CuSO}_4 \cdot 3\text{Cu}(\text{OH})_2$; basic copper chloride (in products near the seaboard) with atacamite, $\text{CuCl}_2 \cdot 3\text{Cu}(\text{OH})_2$; basic-copper carbonate (usually present, but in minor proportion) with malachite, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$. All these minerals are green in colour and are probably isomorphous; their presence accounts for the green patina that characterises copper surfaces after prolonged exposure.

Complete agreement with the formula of the mineral has been realised in products after 70 years' exposure and upwards. After shorter periods of exposure the basicity of the product (ratio of copper hydroxide to normal salt) is lower than that of the corresponding mineral; in extreme cases the normal copper salt may be present.

When lead enters into the composition of the green patina (as happens if lead is an appreciable impurity in the underlying metal) it probably takes the form of the double basic sulphate of lead and copper, corresponding with the green mineral, caledonite.

Sulphide in urban products probably exists in the early stages as black cuprous sulphide (chalcocite), which later oxidises to blue cupric sulphide (covellite), thus permitting the development of a green patina even in the presence of appreciable amounts of sulphide.

THE EFFECTS OF TWO YEARS' ATMOSPHERIC EXPOSURE ON THE BREAKING LOAD OF HARD-DRAWN NON-FERROUS WIRES.

By J. C. HUDSON, D.Sc., D.I.C., A.R.C.S.

THIS paper embodies the results of a subsidiary research undertaken in connection with the field tests on the atmospheric corrosion of non-ferrous metals and alloys conducted by the Atmospheric Corrosion Committee of the British Non-Ferrous Metals Research Association, and forms part of a systematic study of the progressive attack of metals when exposed to pure and contaminated atmospheres. The object in view has a definite practical bearing, as the original suggestion for the research, made by architects, related to corrosion of internal and external non-ferrous metal fittings used in building.

This paper contains details of tests on a number of hard-drawn non-ferrous wires, in which determinations of the breaking load were made before and after exposure to the South Kensington atmosphere for two years. Owing to the fact that appreciable changes took place in the strength of the unexposed wires, it is not possible to arrange the materials in a definite order of merit as regards resistance to atmospheric corrosion. The losses in strength after two years' exposure were, however, very small, and the observations confirm the results of earlier work in showing

that under straightforward conditions the majority of non-ferrous materials are very resistant to atmospheric corrosion. Brass is an exception to this statement, as its strength is adversely affected by the copper redeposition that accompanies atmospheric corrosion. A few remarks are made on the atmospheric corrosion of copper-nickel alloys.

A NEW SILICON-ZINC-COPPER ALLOY.

By Dr. E. VADERS.

As the copper-zinc alloys are of the most interest among copper alloys, the influence of silicon on them has naturally received more attention than on aluminium-bronzes or copper-tin alloys. Guillet concluded, as a result of his researches, that the maximum permissible silicon content of copper-zinc alloys was dependent on the zinc content of the alloy, the greater the zinc content the smaller was the amount of silicon that could be added before the separation of a new constituent rendered the alloy too brittle. This assumption of Guillet, and his statement that only small quantities of silicon could advantageously be added to brass, had the effect of deterring other workers from further investigating the ternary system silicon-zinc-copper. The results of the present work, however, show that silicon-zinc-copper alloys with a higher content of silicon than those prepared by Guillet, are technologically useful, provided that the copper content is sufficiently high. Whilst Guillet stated that zinc-copper alloys with more than 2% silicon were too brittle for use, investigations have shown that quite valuable alloys can be prepared containing more than 2% silicon when the copper content exceeds 70%. The mechanical properties and the technical uses of these alloys form the principal objects of this paper.

The results of this work show that silicon-zinc-copper alloys have a homogeneous solid solution structure up to a much higher silicon content in the copper corner of the ternary diagram than has hitherto been assumed—for example, whereas 2% silicon was thought to be the maximum solid solubility in the 90% copper alloy, it has now been shown that about 4% silicon can be retained in solid solution. These alloys with a high silicon content, especially when it is all retained in solid solution, have valuable properties. They can be worked hot as well as cold. Some of the alloys of this type have outstanding properties as bearing and bell metals.

THE EFFECT OF PHOSPHORUS ON THE STRENGTH OF ADMIRALTY GUNMETAL.

By H. C. DEWS.

THE practice of adding a small amount of phosphorus to the melt during the preparation of gunmetal is common in many foundries, and the opinion is well supported amongst foundrymen that it facilitates the production of sound castings. The manner in which the phosphorus functions is much less widely understood. There are differences of opinion among metallurgists on this point, and adequate enlightenment does not appear possible until many more experiments have been carried out. In this paper the author has made no attempt to discuss the chemical or physical action of phosphorus on molten bronze. The results given are concerned solely with the effect of phosphorus up to 0.131% on the tensile strength, Brinell hardness, density, and microstructure of sand-cast Admiralty gunmetal.

The composition of the heats was intended to be as near as possible to the standard Admiralty gunmetal composition. During melting there was a slight loss of zinc and phosphorus, and a compensating surplus was allowed in the original charges. The effect of casting temperature was nullified by casting from each melt a range of test-bars

at casting temperatures, chosen to cover the range of temperature within which sound castings could be obtained.

The mechanical test results show the effect of phosphorus to be more marked between 0.04 and 0.07%. From a trace up to 0.04% phosphorus there is only a very slight increase in the tensile strength and a slight decrease in the elongation. Above 0.04% the tensile strength and elongation both drop sharply, but from 0.07 to 0.13% phosphorus there is little further alteration in either value. The Brinell hardness is slightly increased as the phosphorus content is increased to 0.04%, and a reduction in hardness with further increase of phosphorus up to 0.13%. There is practically no change in the density with up to 0.06% phosphorus, and a slight reduction as the phosphorus content is increased to 0.13%. The microstructures of the alloys showed no unusual features.

LATTICE DISTORTION AS A FACTOR IN THE HARDENING OF METALS.

By WM. L. FINK, M.S., Ph.D., and KENT R. VAN HORN, M.Sc., Ph.D.

It is the object of this paper to aid in the determination of the importance of lattice distortion in the hardening of metals. The experiments consisted in measuring the hardness and making pinhole patterns of elastically deformed specimens. This was accomplished by reflecting a filtered shaft of X-rays from the centre of the convex surface of a beam supported at the ends and loaded at the middle, and by determining the hardness (Rockwell scale "E") of the same portion of the specimen.

The materials investigated were an aluminium alloy having a nominal composition: copper 4.5, magnesium 0.5, manganese 0.5, and the balance commercial aluminium, and a 70:30 brass. The specimens were machined from 0.25 in. thick cold-rolled sheet. The materials were both treated, the brass was heated 5 mins. at 550° C., and the aluminium alloy 2 mins. at 500° C., to remove internal strains induced by the cold-rolling and machining operations. The specimens were quenched from the annealing temperature to obviate undue grain growth and to harden the aluminium alloy specimens. The surface was polished and etched prior to examination. It was found in certain aluminium alloy specimens that lattice distortion resulting from quenching stresses approximating the elastic limit did not alter the hardness.

This investigation, together with the experiment involved, indicate that considerable caution should be exercised in attributing the hardening of metals to lattice distortion, and also that lattice distortion occurring during precipitation hardening will, in some cases at least, reach a maximum, and partially disappear before maximum hardness is reached.

A STUDY OF THE RELATION BETWEEN MACRO- AND MICROSTRUCTURE IN SOME NON-FERROUS ALLOYS.

By MARIE L. V. GAYLER, D.Sc.

IN the course of a research on the undercooling of some aluminium alloys, it was noticed that in a chill-cast alloy a coarse macrostructure was accompanied by a fine microstructure. The macrostructure of an alloy is that structure which is determined by oblique lighting, and is developed by an etching reagent that attacks the various individual crystals of the constituent which separate primarily. The number of dendritic branches growing from the original dendrite determines the arrangement of the eutectic which solidifies last, and this arrangement is generally known as the microstructure.

In order to find an explanation of these facts, some further experiments were carried out on a tin alloy containing 5% lead, and also on a 7% copper-aluminium alloy, and an 11% silicon-aluminium alloy. The results of a

previous investigation are confirmed—i.e., the higher the temperature from which an alloy is cast, the coarser becomes the macrostructure, and at the same time the microstructure becomes finer, but in a less marked degree.

Variation in the ratio of the cross-section of the mould to that of the casting affects both macro- and microstructure, but, provided this ratio remains constant and the casting temperature is not much above the liquidus, there is little difference in either the macro- or microstructure of alloys whether cast into steel or graphite moulds. If, however, the casting temperature is raised, the macrostructure of the alloy cast into a steel mould is slightly different from that cast into a graphite mould, but the microstructures are almost identical.

The macro- and microstructure of an alloy does not seem to be affected by various gases, provided the casting temperature is kept low. If, however, the casting temperature is raised, the atmosphere to which the molten metal is exposed has a very marked effect on the macrostructure, together with a small effect on the microstructure. Hydrogen, under the conditions mentioned, causes the formation of a fine macrostructure in contrast to that obtained on casting under normal conditions.

It has been shown that a copper-aluminium alloy which has been previously freed from gas by the nitrogen process and then melted in vacuo, still shows inverse segregation; also, the effect on segregation in an alloy which has been exposed to nitrogen or hydrogen has been noted.

It appears that the presence of furnace gases has little effect on the "modification" of aluminium-silicon alloys. "Modification" of a silicon-aluminium alloy cannot be obtained by casting into a heavy, water-cooled copper mould.

"PENDULUM" HARDNESS TESTS OF COMMERCIAL PURE METALS.

By D. A. N. SANDIFER, M.Sc.

THE work described in this paper is an attempt to find out something about the hardness property of substances. There are many different methods by which this property may be measured, but it cannot safely be claimed that any two will measure the same thing, and it was considered advisable to make a careful selection and adhere to one method throughout. The deciding factor in the selection was the desirability, in such an investigation, of measuring the hardness of each substance at its original value, before the test was made, and not some altogether different hardness produced in the test-piece by the measuring instrument. For this reason it was decided to adopt the Herbert pendulum hardness test. In this test the weight of the pendulum is only 4 kilograms, and this weight has to be lowered with extreme care on to the test-piece, so that a negligible amount of work is done upon it.

The investigation was limited to metallic elements, and while many metals had to be omitted from the tests owing to their rarity, samples were secured of 24 metals, from which, with the single exception of arsenic, successful tests were carried out. Pure arsenic could be obtained only in the crystalline form, the crystals being very small and brittle, so that the weight of the hardness tester splintered all the crystals upon which it was placed.

The metals tested were as nearly pure as it was possible to obtain them, without going to an unjustifiable expense, and they were all tested in the primitive or unworked condition, any rolled specimens being annealed before testing. The results of this investigation are entirely dependent upon these conditions.

The author gave a description of the test-pieces, which included aluminium, antimony, arsenic, bismuth, cadmium, chromium, cobalt, copper, gold, iridium, iron, lead, magnesium, manganese, molybdenum, nickel, palladium, platinum, rhodium, silver, tantalum, tin, tungsten, and zinc.

The specimens were prepared for testing in as nearly as possible the same way, and a method of preparation was adopted which would not work-harden them. The method chosen was the same as that used for the microscopic examination of metals. The metals, being very homogeneous, gave consistent results at different parts of the test surfaces.

Time tests were made at ten different places on each sample; a scale test at ten different places, five swinging from 0 and five swinging from 100; three scale work-hardening tests; and one time work-hardening test. Preliminary tests soon showed that the latter is so consistent and accurate in its results that repetition is unnecessary, but with all the other tests, the total number of observations on each metal were averaged.

The author concludes from his investigation that a definite relation exists between the time hardness of any substance at the standard pendulum length of 0.1 mm., and its time hardness at any other pendulum length. This relation has been obtained for the length of 0.21 mm. No definite connection exists between time hardness and scale hardness in the case of pure metals.

If the time work-hardening capacities of the metals are plotted on a time-hardness base, it is shown that the values are low for soft metals, increasing for those of medium hardness, and decreasing again, finally to a negative value, for the hardest metals. This general tendency cannot, however, be represented by any definite equation or continuous curve.

A relation has been established between the values of scale work-hardening capacity and scale hardness for pure metals. The relation is similar to that found to exist in the case of time test, and can be represented by an equation of parabolic form for tests made with a pendulum length of 0.21 mm. It has been shown that the time hardness of metal is directly proportional to its modulus of elasticity, except when the metal is a very hard one. The time hardness of a metal is also related to its atomic volume, provided that the very hard metals are again excepted. The metal antimony is also an exception.

Some quantitative results of the effects of reduction in sectional area by rolling have been obtained for copper, aluminium, and magnesium. In all three cases the gradual increase in hardness produced is accompanied by a gradual decrease in the capacity to be further hardened.

Attention is drawn to the fact that several of the metals of greatest hardness and lowest work-hardening capacity are those which have most remarkable effects on steel when added to it, as indicated by nickel, tungsten, and manganese. It has also been shown that the element selenium has properties which bring it within this group, its scale and time hardnesses being high; its scale work-hardening capacity low, and its time work-hardening capacity, like that of manganese, negative. This being so, it would be interesting to see what effect selenium had on different steels when added to them in a range of increasing proportions.

The Use of Non-Ferrous Metals in the Aeronautical Industry

By D. Hanson, D.Sc., Professor of Metallurgy, University of Birmingham.

The Ninth Autumn Lecture, delivered before the Members of the Institute of Metals at their meeting held at Southampton, from which the following has been extracted.

WHILE it would be incorrect to claim that the conquest of the air has been dependent on the use of non-ferrous materials, it is certainly true that the present state of air communications is in large measure due to the development of non-ferrous alloys, and their use in aircraft construction in large quantities.

The hectic days of the Great War were perhaps responsible more than anything else for bringing the problems of aircraft construction into prominence, and resulted in a period of intense development and progress. The greatest advances from the metallurgical point of view were probably in materials for engine construction, and strong, light alloys contributed in large measure to the evolution of a high-power unit of low weight. Notable improvements in aircraft structures were also made, although for some years after the war wood and fabric were still largely employed. The desirability of using metals had long been evident, and experiments with steel and aluminium alloys had frequently been made, but it is only within the last few years that the difficulties have been surmounted, and that all-metal aeroplanes have become common.

The importance of weight makes it very necessary in designing the structure of any aircraft to avoid any undue mass of metal, while the conditions under which aircraft are used make it equally necessary for the designer to ensure that failure shall not occur in any important member, and in consequence few engineering structures are so carefully and economically designed, from the point of view of the material used, as those of modern aircraft.

Provided that suitable forms can be devised which will

enable the full strength of the material to be developed before instability shows itself, the material with the highest specific strength will produce the lightest member. In those members in which the above dimensional considerations will permit its use, nickel-chromium steel, treated to give a proof stress of about 65 tons per sq. in., is suitable, and is often used in English aircraft for the main wing spars, the beams of the body girders, and so on. Duralumin is little inferior in specific strength; it is distinctly easier to make in complex forms, and is even more extensively used; it is almost universal for parts subjected to moderate stresses, extra rigidity thereby being obtained. With the development of strong rolled magnesium alloys, a further material is becoming available; these alloys possess specific strength as great, or greater, than the alloy steels, and appear capable of still further improvement, although on account of their low modulus of elasticity they are slightly inferior in specific rigidity—a quality which does not appear likely to be considerably improved by alloying. Although experience with them is as yet slight, and they are only in the early stages of their development, they have, nevertheless, shown sufficient promise to be included in the wing spars of the twelve-engined Dornier flying boat, and their development will be watched with great interest.

The stainless steels are other materials containing a considerable amount of non-ferrous metals which have also been used to some extent. The chromium stainless steels are little inferior in strength to the ordinary heat-treated nickel-chromium steels, but the austenitic alloys are soft, and possess a low proof stress and ultimate strength in the normal condition, and suitable properties can only

be obtained at present by cold-working. Those materials have been used extensively in the British airship R101; they will find further use in the future in aircraft construction on account of their rust-resisting qualities.

Aluminium Alloys.

Among the non-ferrous alloys, those of aluminium are at the present time by far the most important; the only serious rivals in sight are magnesium alloys, which are now undergoing rapid development and are steadily finding application in many directions. The principal strong alloys of aluminium, with only one or two important exceptions, contain copper as the chief alloying element—in some cases the only one. In these instances the properties depend mainly or wholly on the influence of copper on aluminium, and could not be obtained by any other known elements or by any combination of elements that did not include copper. Copper has, in fact, the same importance for aluminium alloys as carbon for the steels. This is in part due to the formation of the compound CuAl_2 , which forms a eutectic with aluminium, but more especially to the solubility of this compound in aluminium, and the changes of solubility with temperature, which permit the application of a form of heat-treatment that has a very beneficial effect. Next in importance, perhaps, are silicon and magnesium; silicon and aluminium form important casting alloys, while magnesium, especially in combination with silicon or copper, contributes to the production of high-grade cast and wrought alloys, and the development of their properties through heat-treatment.

Nickel and zinc are also important metals, each of which enters, with copper, into important strong alloys. There remain only manganese and iron: manganese is an improving, though not a major, constituent in Duralumin and similar strong wrought alloys, and iron is sometimes intentionally incorporated in castings to withstand wear. Traces of sodium, titanium, and other metals are used for special purposes.

In a wrought state all the high-strength aluminium alloys depend on the process of heat-treatment for their useful mechanical properties, and one or both of the constituents, CuAl_2 and Mg_2Si , contributes in all cases to the development of these properties.

Aluminium alloy castings find uses in many directions; they enter largely into the power unit, and are used in the structure of aircraft for a variety of small fittings, such as brackets, housings, adaptors, levers, and so on. The different alloys have characteristics which render them suitable for certain applications; sometimes good mechanical qualities at room temperature are required; in some instances strength or hardness at elevated temperature; sometimes resistance to corrosion is important, and in some cases ease of casting in a particular form may be all that is needed. The duty to be performed decides which alloys are suitable.

The use of aluminium die-castings has extended greatly during recent years. They can be finished closely to dimensions, thus eliminating practically all machining, and holes can be placed with great accuracy, while they are cheaper than sand-castings when produced in quantity. They will find an increasingly large application for lightly stressed parts as standardisation and output develop.

Magnesium and its Alloys.

Magnesium is a metal with a great future, and it is only during the last few years that cast and wrought magnesium alloys of high strength have been able to compete with the heavier aluminium alloys, but during this period progress has been rapid; the experimental stage has definitely been passed, and they are now being produced and used in commercial quantities strictly on the basis of their cost and technical qualities.

One of the biggest advances in the technology of magnesium and its alloys has been the perfection of methods of melting and casting in the foundry. The metal is very

reactive, and combines vigorously with atmospheric oxygen at about 650°C . or above, and with atmospheric nitrogen at a slightly higher temperature, and it really burns. Even when actual "burning" does not occur, oxides and nitrides become entangled with the molten metal when it is melted in contact with air. At higher temperatures silica is reduced, Mg^2Si being formed. By melting in wrought iron or mild steel vessels covered with a suitable flux, these difficulties have been overcome. Magnesium does not alloy with iron, and crucible failures always occur from the outside through scaling. The flux used is MgCl_2 , with additions of other salts to reduce its fluidity, and decrease its tendency to dissociate. It not only protects the metal from contact with the air, but also dissolves any oxide or nitride that may be accidentally formed. It can readily be held back while the metal is cast. With reasonable care, by this process, clean metal can be delivered to the moulds with foundry losses of only 1 to $1\frac{1}{2}\%$.

Molten magnesium reacts violently with water, and for some years all sand-castings were cast in dry moulds. The results, however, were not very satisfactory, even with moulds dried at 400°C ., largely owing to the difficulty of driving off the combined water in the clay bond, without destroying the binding power of the sand, and casting defects were common, while the process was costly. The problem has now been solved by the simple expedient of mixing a small proportion of sulphur together with a less quantity of boric acid, with ordinary moulding sand. The molten metal entering the mould instantly vaporises the sulphur in the surface layer, and the vapour appears to protect the metal entirely from reacting with the moisture in the sand; sound, clean castings are produced, and most of the sulphur condenses in the cooler parts of the mould, so that little is lost. Green-sand moulds are used, which are preferably skin-dried for large and important castings.

In other respects, foundry practice is very similar to that required for aluminium alloys; the metal should be poured steadily in a constant stream; heavy sections require adequate feeding, and the use of heavy chills is often desirable.

Magnesium is not one of the easiest metals to work, and considerable care is required. Sheet and extruded sections are being produced in considerable quantities, and are finding many applications. Forgings are also being successfully produced, but there are still problems to be solved before complete success can be regarded as achieved in this direction.

Some Other Metals Used.

Among heavier non-ferrous metals, the use of which is naturally limited, Professor Hanson referred to nickel as an important metal in aeronautics. It is an essential constituent of the high-tensile alloy steels, and of the austenitic stainless steels; and the latter are likely to find greatly extended uses in the future. In these applications it is usually associated with chromium. It is the strongest of the common metals, and possesses an elastic modulus at least as high as iron. Its density is unfortunately high, and in specific strength it is inferior to the alloy steels. It possesses, however, a high degree of resistance to corrosion, and is readily worked, and it may find uses in certain directions because of its special qualities, notwithstanding its greater weight, particularly in seaplanes. Monel metal for pontoons and wing-tip floats are giving satisfactory results without the use of any protective coating; and landing wheels for amphibians and engine water-jackets are also being tried. Freedom from corrosion is specially important in the rivets used in assembling modern metal structures, especially as some of the modern methods of protection against corrosion are difficult to apply to them, and large numbers of Monel metal rivets are now being used in this country for this purpose. On account of their heat-resisting qualities, nickel-rich alloys are also used in engines for such parts as valves, valve seatings, and sparking-plug electrodes.

METALLURGIA

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RESEARCH AND PROGRESS.

THE rapid development of the social structure of the civilised world is due, in no small measure, to the applications of the results of research. In its various forms research has led to discoveries which have had a direct bearing and effect upon human life and human surroundings. It has changed our ideas of disease, for instance, and certainly during the last fifty years we have witnessed a revolution not only in our conception of the nature and origin of disease, but, in the methods of combating it, which have been developed as a result of research. While the preservation and lengthening of life are undoubtedly important, it is just as necessary to ensure an adequate supply of food, and the use of fertilisers to increase the fertility of the soil has become a necessity. The results of research have shown us the extraordinary value of nitrogen in the form of a manure for the purpose. In all the various branches of commerce and industry necessary to the maintenance and preservation of life, investigations are continually in progress with a view to the further development of old industries, and, by means of new inventions, establishing new means for increasing production. It is this continual striving after improvements to increase the material resources of the world for the benefit of mankind that is the duty of the research worker, and the measure of success achieved is, to a large extent, the measure of progress, and what the world owes to metallurgical science is not always realised.

In order that research work will be progressive, authoritative bodies are formed to investigate and seek a remedy for difficulties that continually arise. With a view to concentration these organisations are sectionalised and the sphere of activity of each is defined within reasonable limits. Thus, the papers presented before the members of the Institute of Metals at their meeting at Southampton gave results and conclusions from investigations, dealing primarily with non-ferrous metals, many of which have a definite application to industry. The British Non-Ferrous Metals Research Association have in progress researches on the high temperature properties of certain non-ferrous metals and alloys. The reliable demonstration of the properties of such alloys should immediately result in their application. The tendency in boiler and turbine practice, in internal combustion engines and in chemical plant appears to offer boundless opportunities for alloys such as nickel-chromium on account of their capability of maintaining mechanical strength at high temperatures, and of their resistance to oxidation and corrosive attack. The Iron and Steel Institute, on the other hand, is concerned primarily with the investigation of iron and steel, and research work in connection with these metals and alloys has to investigate high temperature properties necessitated by the increasing pressure at which steam is used. Much research has been done in connection with the properties of steel at elevated temperatures, and the knowledge obtained has been applied in connection with the behaviour of mechanical components that must adequately function when subjected to heat. It would, of course, be impossible here to refer to all the various organisations that are involved in research work of this character, but, while each is concentrating on work within its scope, progress is

dependent upon the suitable application of the combined work of the members of all the organisations. Just as the strength of a chain is determined by its weakest link, so in the case of a more complicated structure, its weakest component will retard the full development of its function. It is this weakest component upon which investigations should be directed, and by continually applying new thought to weaknesses the whole structure will eventually possess greater stability and more fully satisfy demands.

Rapid development has intensified the ceaseless rivalry of commerce and the warfare of industry and research is being directed to the gradual exclusion of labour and to speeding up production by mechanical means. Wasteful rivalry at home is gradually being eliminated as a result of research and manufacturers and producers are combining in order to meet foreign competition more successfully. The need for rationalisation has been forced upon them. Highest output coupled with lowest cost is the desire and reorganisation in an endeavour to effect this result has been in progress for some time in the steel industry. The more recent evidence of the application of this form of research is shown in the shipbuilding industry. About six months ago, it will be remembered, British shipbuilders formed the National Shipbuilders' Security, Ltd., with the primary object of purchasing redundant shipyards, the dismantling and disposing of their contents, and the resale of the sites under restrictions against further use for shipbuilding. The Dalmuir shipbuilding yard of Messrs. William Beardmore and Co., Ltd., has recently been purchased under this scheme, and two other shipbuilding yards are likely to be purchased with the same object in view; negotiations are stated to be in progress concerning a shipyard on the west coast of Scotland, and another on the east coast of England. An official statement claimed that the scrapping of redundant shipyards would not mean less employment but increase the chance of remaining yards securing more contracts in foreign competition and would thus provide greater employment, as concentration of production means reduction in costs.

Although it is possibly true that less employment is not likely to result, it can only be applied in the widest sense, and does not apply particularly to the workpeople about to lose their employment in the yards dismantled. The increasing use of machinery has caused a remarkable increase in the fruitfulness of human industry, and, under present conditions, production is greater than demands, with the result that surplus labour retards and clogs the wheels of progress. This is the weak link preventing further rapid development in social progress; there is a pressing need for research to restore the balance, not only because the unemployed are becoming daily more demoralised and gradually sinking below the level of efficiency, but because, in the widest sense, progress is dependent upon the continued development of each section. Every effort should be made to restore stability to the social structure; it requires the same degree of energy and determination as is necessary in meeting demands to overcome weaknesses in other structures. The most authoritative body to adequately cope with such an investigation is the Government, and with goodwill and an exhaustive enquiry we are optimistic enough to believe that it would have far-reaching consequences in facilitating progress.

DETERMINING MACHINABILITY.

METALS and alloys are continually being developed to meet more exacting and strenuous conditions. Comparatively small percentages of alloying elements frequently have a remarkable effect on the mechanical properties of metals which render them eminently suited for particular purposes. In addition to modifications that may result from the addition of other elements, metals are often subjected to various treatments so that they may possess certain characteristics not present in the untreated condition. In view of the diverse characteristics of metals machining difficulties frequently arise in the machine shop. Under present conditions production in the machine shop is dependent on much experimental work, particularly when the work to be done is of a repetition character. In such instances the machine and tool require to be designed and adjusted to give the degree of accuracy and finish desired, and in the shortest possible time. The experimental work that is done to determine the best conditions to give the desired result is dependent largely upon experience, and as metals and alloys differ so widely the conditions under which they can be machined to the best advantage are also variable. Each newly developed metal and alloy must be studied in the light of experience, and the results considered to be the best in one machine shop differ considerably from those obtained in another machine shop using similar metal. This rather expensive method would be entirely unnecessary, or at least the conditions would be more readily determined, if some means were available for determining the quantitative relationship between the machinability of a metal and its tensile strength, hardness or any other physical characteristics which it possesses. Many investigations have been undertaken with this object in view, but in many instances these investigations have been made under conditions that are entirely unsuited to workshop practice. Obviously, unless a measure of machinability can be definitely applied in the workshop, it is of little value in solving production problems involving the machining of metals.

The subject is very complex, and investigations, to be of any real value, should be made under conditions similar to those actually in operation in the workshop. Investigations of this character have been undertaken by Mr. E. G. Herbert, who begins a series of articles on "Machinability" in this issue, from which he found that machining processes change the physical properties of metals to which they applied, and concluded that no quantitative relationship can exist between the machinability of metals and the physical properties which they originally possess, and which have not been changed by machining.

Further, in metal-cutting operations, whether conducted with acute angle or obtuse angle tools, he found that actual cutting is done by the built-up edge which begins to form immediately on the commencement of cutting. The efficiency of the cutting process, and therefore the machinability of the metal, he concluded, depended on the natural angles of the built-up edge rather than on those of the tool which serves to support it.

Mr. Herbert arrived at many conclusions of a valuable character as a result of his investigations, which he will discuss, and, in addition, will indicate the salient points in the work of other investigators and endeavour to show the practical value and the possibility of further research on the subject likely to lead to a profitable result. There is no doubt that the machine tool designer, no less than the machine-tool user, would welcome some scientific basis for determining the machinability of metals, whether as a function of some known factor of the material, or as a definite measurable property in itself, providing the application was reasonably simple and practical. Any metal or alloy, however recently developed, would then be machined under conditions rapidly determined, capable of giving the best results, and thus facilitating production.

Autumn Meeting of the Iron and Steel Institute.

THE autumn meeting of the Iron and Steel Institute, to be held from September 15—20, takes place under the patronage of the Czechoslovak Government and by kind invitation of the Society of Czechoslovak Engineers, with the support and co-operation of the Iron and Steel Industrialists of Czechoslovakia. The arrangements for the meeting have been carried out by an influential committee and the sessions take place on September 15 and 16; the subsequent arrangements include visits and excursions to the principal iron and steel manufacturing and engineering establishments in Czechoslovakia.

On the first day an official welcome will be extended to the Institute by Dr. V. Sykora, President of the Society of Czechoslovak Engineers, by His Excellency Dr. J. Matousek, Minister of Commerce, Industry and Trade, by Dr. K. Baxa, Lord Mayor of the City of Prague, and by Dr. A. Sonnenschein, Managing Director of the Vitkovice Mines, Steel and Iron Works Corporation, as representing the Iron and Steel Industry; following which the Institute will hold a business meeting, and at the conclusion the following papers will be presented and discussed as time permits:—

No. 3. A. KRIZ: "The Heterogeneity of an Ingot made by the Harmet Process."

No. 7. J. SAREK: "What Reasons Compelled the Prague Ironworks to Introduce Thin-walled Blast-furnaces."

No. 2. W. H. HATFIELD: "Permanence of Dimensions under Stress at Elevated Temperatures."

On the second day the session will be devoted entirely to the consideration of papers, and the following are expected to be read and discussed:—

No. 5. O. QUADRAT: "A Contribution on the Problem of the Analysis of Basic Slags, and the Representation of their Composition in a Triangular Diagram."

No. 11. H. C. WOOD: "Open-hearth Furnace Steelworks. A Comparison of British and Continental Installations and Practice."

No. 1. D. F. CAMPBELL: "High-frequency Steel Furnaces."

No. 8. L. W. SCHUSTER: "The Effect of Contamination by Nitrogen on the Structure of Electric Welds."

Forthcoming Meetings

Additional meetings have been arranged to take place after the autumn general meeting at the following centres:—

October 6. Middlesbrough: At the Cleveland Technical Institute at 7-30 p.m., Papers: Nos. 3, 5, 7, 8, and 11.

October 7. Sheffield: At the Metallurgical Club at 7-30 p.m. Papers: Nos. 1, 2, 3, and 11.

October 7. Scunthorpe: At the Secondary Schools, Doncaster Road, at 7 p.m.

Papers: No. 11, and the two by F. Bainbridge (12) and by J. A. Jones (13) read at the London May meeting of the Institute.

October 10. Swansea: The Royal Metal Exchange, at 7 p.m. Papers: Nos. 3, 5, and 11.

October 17. Glasgow: At the Societies' Rooms, Royal Technical College, at 7-15 p.m. Papers: Nos. 7 and 11.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

October 10. The "James Watt" Dinner at the Grosvenor Restaurant, Gordon Street, Glasgow.

THE JUNIOR INSTITUTION OF ENGINEERS.

The opening meeting of the fiftieth session will be held on Friday, October 3, 1930, in the lecture room of the Institution at 39, Victoria Street, S.W. 1, at 7-30 p.m., when a lecture, entitled "The Development of the Bridge" will be delivered by Mr. S. J. Crispin (Member), illustrated by a large number of original slides.

Tungsten-Carbide Cutting Materials

Operators must be trained to adopt proper methods as the technique involved is different from that of steel tools.

AS a result of a questionnaire sent out to a large number of firms, a Sub-Committee of the A.S.M.E. Special Committee on the Cutting of Metals have prepared a digest of fifty replies; representing experiences with the use of tungsten-carbide tools, from which the following information has been prepared.

The returns show that a relatively small average number of machining operations are now being regularly performed, using tungsten-carbide tools, but while the total volume of production now being obtained with the use of these tools is relatively small, practically all the firms contemplate the more extensive use of tungsten carbide, providing tests, which are being carried out, prove satisfactory.

Experiences indicate that tungsten carbide is superior to tool or high-speed steel as a cutting material on all non-ferrous metals, regardless of the hardness or the condition of the surface, especially for roughing cuts on production jobs. Not all are agreed, however, that finishing can be done as satisfactorily as with high-carbon or high-speed steel tools, because tungsten carbide is comparatively weak and brittle, and will not hold a fine, keen edge.

Cast iron submits readily to the tungsten-carbide tools even when the surface has a hard, sandy scale. One company reports that tungsten-carbide tools do not seem to fail in cutting through chaplets and welds, where blow-holes have been acetylene welded.

Opinions Differ.

A difference of opinion exists as to the advantage of using these tools in machining steel. Several report failures in attempts to improve on high-speed steel performance, while others are enthusiastic about the use of tungsten carbide for machining steel, and report having readily machined alloy steels which could not be machined economically with high-speed steel. One company reports machining a hand-forged nickel-chromium steel airplane propeller shaft, which was extremely tough and irregular in shape, necessitating, in frequent instances, heavier cuts on one side than on the other. Scale conditions and hard spots were particularly difficult. According to the report, the job was successfully completed, using tungsten-carbide tools, after having found it impossible to finish the machining of the parts using high-speed steel tools, without first annealing the forgings, and then only with great difficulty.

The machines which have been used successfully on regular production include practically all standard types of metal-cutting machines, except milling and drilling machines, which, replies indicate, have been equipped with tungsten-carbide tools for use principally on an experimental basis.

Practically all of the tools used by the companies reporting were lathe or planer-type tools, in a large variety of shapes and sizes, some having shanks as large as 2 in. \times 2½ in. Tips in most cases were simply brazed, though a few were inserted, and in one or two cases they were dovetailed and brazed. The rake and clearance angles in most cases were those recommended by the suppliers, but in some instances customers found modifications of these angles desirable on certain kinds of work.

The increase in cutting speeds using tungsten-carbide tools in cutting cast iron and non-ferrous metals have been from two to three times the cutting speeds using high-speed steel tools. Many are using the highest speed that the machines will permit, and the general practice seems to be to use about the same feeds and depth of cut in cutting with tungsten-carbide tools as with high-speed steel tools. No radical differences have been reported. A tendency

is indicated, however, toward lighter feeds, with much higher cutting speeds than are used with steel tools.

Some remarkable increases in outputs per grind using tungsten-carbide tools for machining cast-iron and non-ferrous metals were reported, as compared with high-speed steel tools.

Practically all of the experiences reported indicate that this material possesses possibilities for the improvement of machining practices far beyond those already attained, provided further improvement is made in the material and in the tools and machines to withstand the more severe service to which they will be subjected. There is still much to be done, especially in the design of machines, and a consideration of some of the suggestions which have been submitted for their improvement. Thus, it is suggested that utmost rigidity of the frame, driving-shaft and spindle, tailstocks, or other members subject to strain, is essential in order that deflections shall be extremely small.

Large-capacity ball bearings, preferably preloaded, or adjustable roller bearings of precision quality, should be used for spindles to withstand heavy loads and to eliminate bearing clearances or reduce them to a minimum.

Considerably higher speeds are obviously necessary, and greater power should be provided, with a large allowance for overload, so that machines will not stall when cutting.

It is important that feeding mechanisms be designed to eliminate jumping due to the building up and sudden release of pressure on tools; tool holders should be heavier, and designed to eliminate the overhang of tools, and the method of clamping tools in holders should be improved to ensure rigidity, and better provision for handling chips and for protecting operators from flying chips.

Conclusions from a Consideration of these Experiences.

Tungsten-carbide tools have been on the market for about a year and a half, but their use on production work is very limited as yet. A year ago it was thought that the development of tungsten carbide with respect to material and tools would progress much more rapidly than improvements would be made in adapting machines to the use of this material. This does not seem to have been the case. Improvements in the quality of the material and in the efficiency of the tools and machines seem to be advancing together. The improvement of the machines, however, is a large undertaking, and we may expect important changes in design for some time to come. A large amount of evidence proves that for certain classes of work tungsten-carbide tools can be used with considerable economy on old-style machines, provided they are in good condition. These tools are being experimented with by a large number of machine-tool users, in an endeavour to adapt them to present machine set-ups.

The technique involved in the use of tungsten-carbide tools is quite different from that involved in the use of steel tools, and it will take some time to train shop people in the proper methods of handling, grinding, and setting up tools and machines. The development of this technique is rather expensive, but if the initial applications are made where appreciable saving can be effected, the cost of further and more difficult applications will be compensated for, at least to some extent. A wide demand for machine equipment from which maximum efficiencies can be obtained with the use of tungsten-carbide tools will undoubtedly develop with experience gained from applications on present equipment.

The Problem of Machinability— Measurement

By Edward G. Herbert, B.Sc., M.I.Mech.E.

A scale of machinability analogous to scales of hardness and tensile strength would assist choice of materials for specific purposes.

AN accurate knowledge of the machinability of the metals used in mechanical construction would be of great assistance to the production engineer, since the machining of metals lies at the very foundation of mechanical engineering. The cost of machining metals enters as an important factor into engineering costs, and a scale of machinability, analogous to the scale of hardness and of tensile strength, which is easily available, would be of the utmost assistance in the choice of materials for specific purposes, in the preparation of estimates of costs, and in the fixing of piece rates.

A great deal of research work has been done in this country and abroad, notably at the Bureau of Standards, Washington, at the University of Michigan, and at the Technical High Schools of Aachen and Charlottenburg, in the hope of finding some method whereby the machinability of metals could be deduced from their known physical properties; but in spite of all the work that has been done, no generally applicable method of deduction has been found, no scale of machinability is available, and reasons will be given for doubting whether such a scale can ever be attained.

Determination by Measurement.

To establish a criterion of machinability does not at first sight present any special difficulty. We might, for instance, decide to measure the machinability of metals by the weight that can be removed per hour under standardised cutting conditions. This method of measuring machinability would appear to be both logical and practical, but if we attempt to apply it we are at once confronted with difficulties.

If the results of the measurements are to be strictly comparable, all the tests must be made under identical conditions with the same shape of tool, cutting at the same speed with the same feed and depth of cut, and if they are to bear any relationship to workshop practice the tests must be made under workshop conditions. But it will be seen at once that if an average set of workshop conditions is selected as the standard, it will be impossible to cut the harder materials at all, whereas if the conditions are so chosen as to allow the most difficult metals to be machined, they will be quite inappropriate to some, and probably to most, of the materials under investigation. This method would involve cutting, say, a soft, free-cutting steel at a speed and with a shape of tool suitable for machining high tensile alloy steels. The results would bear no relation to normal workshop practice, and, moreover, no measure of machinability would be obtained, since the weight of metal removed in unit time would be the same in every case. It would depend simply on the speed, feed, and depth of cut selected.

We must therefore abandon the idea of making all tests under the same conditions, and, instead, we must select the highest speed and the most suitable tool-shape for each particular metal, but to do this would necessitate a pre-knowledge, or at least an assumption, of the machining properties of each material. The results would be the respective weights of metal removed under a diversity of cutting conditions arbitrarily chosen, and they would

not have much more value than the kind of general knowledge of the materials which was used in selecting the test conditions.

Another possible criterion of machinability would be the power consumed when cutting various metals under uniformly standardised conditions. Here, again, we are confronted with the difficulty of selecting conditions which are at once in conformity with workshop practice and adapted to all metals from the softest to the hardest. Obviously, no such conditions exist. Moreover, the power consumed, though it is easily measured in the case of an electrically driven machine, consists of two parts, the power consumed at the point of the tool, and the power consumed in overcoming friction in the machine itself, and the second part is not a constant, but varies with the stresses at the tool point. It would be easy to find the power consumed in running the machine light, but quite erroneous to assume that this machine loss is the same when cutting hard or soft materials.

Yet another and in some ways a better measure of machinability is the speed at which the metal can be cut, the feed and depth of cut being kept constant. If this method were adopted, it would be necessary to take into account another, and a rather troublesome, factor—the life of the tool. A standard tool life must be assumed—20 minutes, an hour, two hours,—and a series of tests must be made at gradually increasing speeds until the precise speed is found at which the tool will fail in the standard time. Obviously, such an investigation would be of a most formidable character, involving such an expenditure of time and materials as to place it altogether outside the scope of the privately owned workshop. Moreover, it has the undesirable feature that tool durability must be assumed to be constant, or the inevitable variation between individual tools must be allowed for, by multiplying the tests and averaging the results.

In taking cutting speed as the measure of machinability, it is, indeed, possible to make use of a certain relationship between speed and tool life, in order to obviate the necessity of finding by experiment the exact speed which will cause the tool to fail in the standard time.

It was first laid down by F. W. Taylor, and afterwards confirmed by other experimenters, including the Manchester Lathe Tools Research Committee, that the relationship between cutting speed and tool life may be expressed by the formula, $VT^n = C$, in which V is the cutting speed in feet per minute, T is the tool life in minutes, and C is a constant depending on the cutting conditions other than speed. By giving an appropriate value to n , it is thus possible, after having found by experiment the life of the tool at any given speed, to calculate the speed which would cause the tool to break down at the end of the time selected as standard.

This method was adopted by French and Digges in their investigation ("Rough Turning, with Particular Reference to the Steel Cut"; Amer. Soc. of Mech. Engineers, 1926), carried out at the Bureau of Standards, Washington. These investigators took the value of $n = \frac{1}{4}$, and, by the use of this device, did succeed in placing some

45 steels, different in composition or in heat-treatment, in the order of merit judged by "Taylor Cutting Speeds"—that is, the speeds which would cause the particular tools employed to fail after cutting 20 minutes under the particular cutting conditions adopted.

This was a notable work, which, occupying, as it did, three years, and involving the use of 1,000 tools and the cutting up of 30 tons of steel, is deserving of all praise for the thoroughness with which it was carried out. The results are given in the form most useful to engineers, since the speed at which a given metal can be cut is a good indication of the cost of cutting it. When, however, we attempt to appraise the actual value of the results to the practical engineer, we must take account of some important qualifications.

The results apply to a range of steels whose composition and physical characteristics are given, but no qualitative relationship could be found between the "Taylor Cutting Speeds" and the hardness, tensile, or any other physical characteristics of the steels. Except, therefore, in relation to steels corresponding in all respects to those investigated, the results of French and Digges' investigation would not give any certain indication of machinability, and such an exact correspondence could scarcely be expected to occur very frequently in practice. Moreover, the results

made later to recent work by Professor Wallich and his associates, who claim to have found a direct relationship which can be used for this purpose, subject to certain limitations.

The problem of machinability has been attacked by several investigators working on the assumption that the machinability of a metal can be measured by the force or forces on the tool used to cut it. Thus, the forces on a planer tool have been measured by Professor O. W. Boston (University of Michigan), the forces on a lathe tool by Professor Dempster Smith (Manchester), and by Boston, Wallich, and Schlesinger; while the torque exerted by a twist-drill when drilling holes in metals has been measured by these investigators, and by Patkay (Charlottenburg), and by Benedict and Hershey (University of Illinois).

It cannot be denied that these investigators have elicited much information of an interesting and useful character, but the methods employed have this in common—they all involve the use of complicated and expensive dynamometers by skilled investigators. They are essentially methods for the research laboratory, rather than the workshop. An accurate knowledge of the forces which tools have to exert is of great value to the designer of machine tools, but to the engineer who has to machine

metals, and is primarily concerned with questions of output and cost, a knowledge of the forces exerted by the tools he uses is not of much direct interest unless it can be translated into terms of output and cost, and it is doubtful, to say the least, whether any such translation is possible.

A more direct method of measuring the machinability of metals is that which depends on the permissive feed, the tool being set to cut under standardised conditions, and the machinability of the metal being measured by the amount of machining actually done in unit time.

The most common application of this principle is that of the loaded drill. The weight of the drill spindle, plus a certain added weight, constitutes the feeding mechanism and frictional resistance being as far as possible eliminated, the machinability of the metal is measured by the depth of hole drilled in a given time, or by the time required to drill a hole of a given depth. This method is one requiring special appliances. It cannot be carried out on the workshop drilling machine,

and it is subject to special disadvantages. The cutting action of a twist-drill is different from that of every other tool. The point of the drill can scarcely be classed as a cutting tool, and the speed is different at every part of the lip. Most important of all, it is almost impossible to regrind a drill so as to duplicate the results. Thus, Boston says: "All of the drill penetration tests of this paper ["Methods of Tests for Determining the Machinability of Metals in General, with Results"; O. W. Boston, Amer. Soc. for Steel Treating, 1929], were obtained with the same drill and with one grinding, as it was found almost impossible to regrind the drill, even on a machine, to give results comparable with those of the first grinding." For these reasons the drill penetration test is hardly likely to give results of general application. The weighted spindle has been used by Wallich and Krekeler for permissive feed measurements of machinability with a revolving work-piece and a fixed turning tool, with a cupped grinding wheel attached to the spindle, and with a revolving work-piece attached to the spindle and brought to bear on a fixed face-milling cutter.

A form of permissive feed test for machinability introduced by the present writer has the merit that it does not involve the use of any but standard workshop equipment, while the test can be made very quickly by any mechanic.

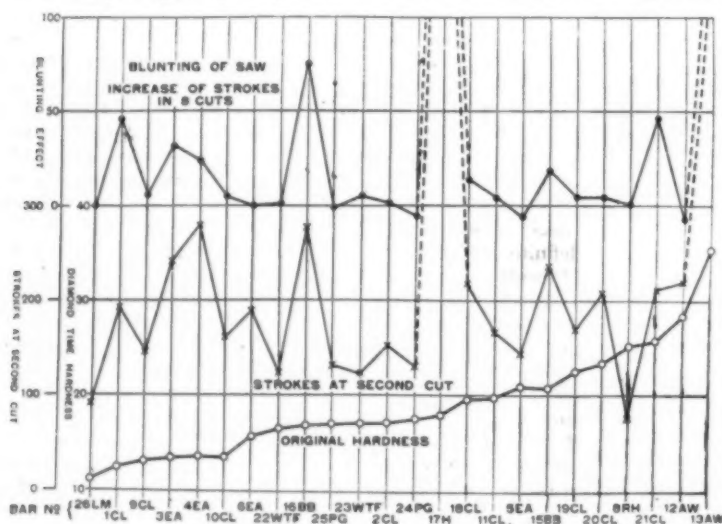


Fig. 1.—Results of Sawing Tests Summarised.

would apply only to the particular cutting conditions adopted in these experiments—a tool of a particular shape having a section in the body of $\frac{1}{8}$ in. \times $\frac{1}{8}$ in., cutting dry with a feed of 0.028 in., and a depth of cut of $\frac{3}{16}$ in. There is reason for believing that any considerable departure from these conditions might have placed the steels in a different order as regards machinability.

Although the work of French and Digges is perhaps the most notable attempt that has been made to place a large number of typical steels in the order of their machinability as measured by the speed with which they could be turned under certain specified conditions, their work does not stand alone. No attempt will be made to review the various investigations which have been made or somewhat similar lines. It must suffice to say that what French and Digges have done for a series of American standard steels, has been done for many typical German steels by Professor Wallich and Dr. Krekeler at Aachen, and by Dr. Schlesinger at Charlottenburg. These investigators have put on record a vast amount of classified information relative to the machining properties of standard steels, but they have failed to give the engineer what he most needs—a simple means of measuring or calculating the machinability of any steel or other metal which he may have occasion to use. Reference will be

This test consists in making a cut with a gravity-fed hacksaw through a bar of standard diameter, say $1\frac{1}{2}$ in. or 2 in., and counting the number of strokes taken in cutting through the bar. In making the test it is advisable to use a sawblade sharpened to a standard shape of tooth on an automatic saw-grinder, and to use a newly sharpened blade for each test. In the investigation carried out by the writer ("Report on Machinability"; E. G. Herbert. Inst. of Mech. Eng., 1928, No. 4) the sawblade used was of high speed steel, and had the set carried into the body of the blade, so as to permit of repeated sharpening without loss of side clearance. All tests were made with the freshly sharpened blade, and after the investigation of 26 different metals, involving 26 sharpenings of the blade, sufficient set remained for at least another 25 tests.

As a practical workshop test of machinability involving the use of none but standard workshop equipment, and capable of being carried out in a very few minutes by persons possessing no special skill, the hack-saw test is certainly worthy of attention. Moreover, it is capable of yielding two distinct and independent measures of machinability. In the investigation referred to, ten cuts were made through each bar. The number of strokes taken by the first (or, preferably, the second) cut was a measure of resistance to cutting, while the difference between the number of strokes in the second and tenth cuts was a measure of the blunting effect of the particular metal.

The results of the sawing tests are summarised in Fig. 1.

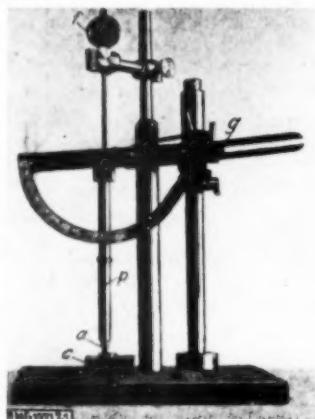


Fig. 2.—The Leyensetter Pendulum.

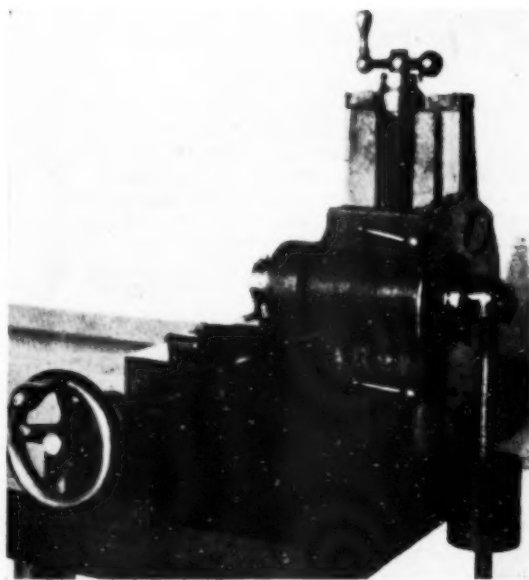


Fig. 3.—A Milling Dynamometer.

reproduced from the Report. The various bars are arranged in the order of their hardness (measured by the Pendulum Time Test), and it is apparent that the hardness gave no indication whatever of the machining properties of the metals. Among the most difficult metals to cut were a soft chrome vanadium steel (4 E A) and a stainless

steel of low hardness (16 B B). A soft manganese steel (17 H) and a 90-ton nickel chrome molybdenum steel (13 A W) could not be cut under the conditions adopted. The easiest metals were soft wrought iron (26 L M) and hard cast iron (8 R H). In several instances, notably that of the 80-ton "Vibrac" steel (12 A W), the "increase of strokes in eight cuts" was negative, the rate of cutting actually increasing as the saw became worn. This curious phenomenon is attributed to the formation of a "built-up edge" on the saw teeth, and will be referred to later.

Although the hack-saw test with permissive feed was shown to be capable of quickly yielding information of practical importance, reasons will be given for the exercise of caution in attempting any general application of machinability data obtained by this or any other method of cutting. It will be shown that machinability is not to be regarded as an attribute of a metal, but of a metal and a machining process. Any considerable departure from the cutting conditions adopted in the test is liable to change not only the absolute but the relative values to be attributed to the machinability of different metals.

In briefly reviewing the various methods that have been used to measure machinability, it is necessary to refer to certain machines which have been designed specifically for that purpose. One such machine, Fig. 2, is known as the Leyensetter Pendulum. A tool (a) of special form is fixed in the end of a pendulum (p) which is allowed to swing from a fixed position. The tool passes across the specimen (c) and removes from it a wedge-shaped chip, while the pressure exerted by the tool in cutting this chip is measured by a dial gauge (f) attached to a secondary pendulum. If repeated cuts are made, the tool is blunted somewhat, and the increase of pressure shown by the gauge is taken as a measure of the blunting effect caused by a given number of passes. No very definite information is available as to the practical value of results obtained with this instrument.

Another instrument, known as a milling dynamometer, designed by Carl Oxford and described by Boston, consists essentially of a horizontal spindle with a cutting tool fixed in one end, and a heavy pendulum attached to the other (see Fig. 3). The pendulum is first allowed to swing from the top vertical position, and the position to which it rises after a free swing is indicated by a pointer on a dial, and is taken as the zero reading. When a specimen is placed on the table so that the tool cuts it in passing, the pendulum rises to a lower position, which is again indicated on the dial. The difference between the zero reading and the reading obtained with the tool cutting is a measure of the energy expended in the cut. As a practical means of measuring machinability, the Oxford machine does not appear to have created a very favourable impression on those who have used it. Thus, Boston says of it (page 34): "While consistent results may be obtained throughout a number of tests on a single specimen by the single-tooth milling cutter used in an impact type of machine, results from a number of steel specimens do not compare favourably with the results of other methods of tests on the same specimens. This may be due to the fact that the cutting quality of these materials changes with the type of cut and thickness of chip."

(To be continued.)

The Institution of Heating and Ventilating Engineers' Examinations.

EXAMINATIONS for admission as graduates and associate members of the above Institution are held at suitable centres in January, May, and September of each year. Branches for associate members and graduates are in existence in London and Manchester and are being formed in other centres, where there is a special demand, in order that members of these grades may have the advantage of frequent meetings. Applications for membership and intending candidates should apply to the Secretary, H. B. Watt, 12, Russell Square, London, W.C. 1.

Power for Moulding Machines

By A. S. Beech

(PRESIDENT, FOUNDRY TRADES EQUIPMENT AND SUPPLY ASSOCIATION).

Renewed attempts to rekindle an old argument have been heard by the Author and he discusses the merits and demerits of the various motive powers employed.

THE use of electricity, either through magnets or applied through the medium of gears, cannot yet be said to be a serious competitor to pneumatic or hydraulic methods. Various difficulties, such as direct current, or alternating current, appear when endeavouring to use electricity, and the fact that voltages and supplies of electricity vary throughout the country, means that each machine, even if electricity could be universally used, would have to be built specially to suit users of the existing current and voltage in the various works, and this would increase the cost of the machine enormously, and so consideration here will be restricted to two well-known agencies—viz., compressed air and hydraulic power.

It must be emphasised in the first place that there are some cases when compressed air is the better power to use, and other certain cases when hydraulic power is superior. These cases can be briefly summarised as follows:—

The use of compressed air is always advocated when a jolting action is necessary. This immediately opens up a controversy as to whether it is better to jolt or squeeze a mould or whether it is better to do both—viz., jolt and squeeze. The opinion of the writer is as follows:—

(a) Jolting only should be used where one has deep pockets of sand to ram, such as in the case of the long, ribbed radiator pipe of the Continental type, or where any deep narrow parts of sand have to be definitely rammed.

The same remarks apply to the jolt-squeeze type of machine—the only function the squeezing is fulfilling in this case is to tightly ram the top part of the mould after jolting, and eliminating the flat or butt ramming by hand, which is always necessary after jolting. Ingot moulds or long cylindrical patterns should be always jolted or jolt squeezed.

(b) Efforts have been made on many occasions to discount the benefits to be derived from plain squeezing, and many attempts have been made to bring out alternative means to obtain perfectly rammed moulds by other means, at somewhere approaching the same rapid speed. Up to the present these efforts have generally failed, and it is still accepted in America and in Europe that where a plain squeeze can be applied it is not only quicker, but also gives a superior mould. Within the last few years the new application of the "down sand frame," whereby the pattern is pushed into the sand (instead of the sand into the pattern), and drawing the pattern on the exhaust stroke of the piston, has absolutely revolutionised mechanical moulding by pressure, and certainly this method is, without doubt, the most interesting and progressive step which has been made in mechanical moulding within the last decade. By its aid, castings as shallow as flat stove plates, or as deep as baths, etc., can equally well be rammed at a speed which is positively amazing.

In addition, bars in a box are solidly rammed underneath, without any hand tucking, and this fact alone is a great progressive step in mechanical moulding, and, as far as the writer knows, this under-bar ramming cannot be carried out by any other means of mechanical ramming. A further advantage is that moulds have not to be strickled after ramming. It takes valuable seconds to strickle rammed sand. When using the down sand frame, the box is strickled before ramming—that is to say, the loose or unrammed sand

is simply scraped off,—which is obviously much quicker and easier to accomplish than with rammed sand.

It will thus be seen that:—

1. Compressed air can be used for squeezing alone, jolting alone, or jolt-squeeze combined. It can also be used when squeezing only with the down sand frame.

2. Hydraulic pressure serves its best purpose when used for squeezing only, particularly when used in conjunction with the down sand frame.

At the same time, certain facts must be borne in mind when considering which power to adopt.

(a) Compressed air in foundries is generally used at a maximum pressure of 70–90 lb. per square inch. Thus, if the ideal mould, by squeezing only, is to be obtained, the diameter of the cylinder has to be increased considerably in order to give the necessary total pressure to the mould. Against this, hydraulic pressure is usually available at a pressure of 750 lb. per square inch up to very high pressures, thus the cylinders can be considerably less than the pneumatic ones to obtain the same pressure.

(b) The cost of producing compressed air is extremely high. If users would only go into the cost of horse-power to produce the air necessary for the machines, the writer is certain that they would find good reasons for watching the consumption. In fact, there is no doubt that compressed air is the most expensive power in existence. Against this, hydraulic power is probably the cheapest power known to man. The writer does not intend to go into long details to prove this, but it should suffice to say that in the foundry with which the writer is connected twenty hydraulic moulding machines, including several fairly large ones, are all driven with a 5 h.p. motor, whereas two very small compressed-air machines are using over 10 h.p.

(c) Much has been said about leakages in hydraulic installations. It is certainly true that if a leak occurs in a hydraulic main, with, say, 1,000 lb. pressure per square inch, it certainly is a source of mess and inconvenience. But suppose we look at this in another way. Can it be said that compressed-air lines never leak, and if they do, are they noticed? If a hydraulic leak occurs, steps must of necessity be taken to stop the leak, but if compressed air leaks happen, very often they are allowed to go on, either intentionally or otherwise, and, as it has been pointed out, at a very high cost. It perhaps is not generally known that a $\frac{1}{4}$ in. hole in a pipe-line, with compressed air at 75–80 lb. per square inch, will consume the energy of approximately 20 h.p. to overcome the leakage.

(d) Much has been said about freezing of the water in hydraulic installations during winter. It must be admitted straight away that this is a disadvantage to the hydraulic installations, but is it not a fact that this danger is greatly exaggerated? Condensation in pipe-lines of compressed-air installations has also to be watched during the winter months. In either case, only very severe conditions would cause a break, and care should be taken in both cases to drain the pipe-lines and machines, if the weather is sufficiently severe to warrant it.

It must also be remembered that if the weather was so severe as to freeze up the machines, it would also freeze up the sand in the foundry, and work would not be possible. Generally speaking, anyway, in these islands we do not

(Continued on page 188.)

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Rapid progress made in the uses and production of aluminium sheet which has necessitated considerable improvement in operating methods, and, in this article, Dr. Anderson begins a discussion devoted primarily to the manufacture of aluminium sheet as a semi-finished product, but which will also include comprehensive information germane to the subject.

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SO far not much information of value has been published on aluminium sheet-rolling practice. As is the case with various other branches of industry, the practice in aluminium and aluminium-alloy sheet production is advanced far ahead of the literature of the subject. About 10 years ago the present writer and M. B. Anderson⁷ published a series of articles dealing with the rolling of aluminium sheet. The production and use of aluminium and aluminium-alloy sheet have made great strides in the last decade, and many improvements in operating methods have been witnessed. Thus, the large-scale production of heat-treatable aluminium-alloy sheet is a development of recent years; special technique had to be worked out for the successful rolling of this class of material. The rolling of aluminium and aluminium-alloy sheet has also been discussed by the writer¹⁰ in another place. In the present series of articles it is proposed to deal *in extenso* with the manufacture of sheet in aluminium and its alloys. The discussion will necessarily reflect to a considerable degree the writer's own experience, and be presented from the American point of view. However, methods of operation employed in Europe and elsewhere will not be ignored, and due consideration will be given to all sources of information available. With the increase in the number of aluminium-rolling mills in the past 20 years, and the great diversification in the use of aluminium-sheet products, a detailed discussion of sheet-rolling practice may be found of rather wide interest.

The scope of the present series of articles will be confined in the main to methods of manufacture, but some additional information germane to the general subject will be included. Thus, considerable attention will be given to machinery and other equipment and to their maintenance. The mechanical properties and applications of aluminium and aluminium-alloy sheet will be discussed in later articles, but the fabrication of sheet products by drawing, stamping, and other working will not be dealt with. In other words, the object of these articles is to discuss the production of aluminium sheet as a semi-finished manufacture. The various processes required from the unloading of raw metal to the packing and shipping of finished sheets will be detailed. Since the feeling persists in many quarters that aluminium-sheet rolling is a highly profitable business the economic aspects of the matter will be given some attention. Finally, the technical control required in the operation of the modern aluminium-sheet rolling mill will be taken up at some length.

It is sometimes thought that the production of aluminium (or aluminium-alloy) sheet is a very simple process, not to be compared with steel or brass rolling in intricacy of detail and supervision required. This is an erroneous idea, as will be more apparent presently. In a debate in the United States Senate in February, 1930, on the American aluminium import duty, aluminium-sheet rolling is described by Senator T. J. Walsh as follows:—"It will be understood that the bauxite being cleared of impurities it is treated in an electric furnace, and the product comes

out in the form of ingots or pigs. The ingots or pigs are then subjected to heat and passed between steel rollers. The sheets are produced as a result of this part of the manufacturing process. . . . It is a perfectly simple process. It involves no considerable amount of labour. It is all done by machinery. It is just a mere matter of flattening out the ingots into sheets. . . ." Reference will be had from time to time in subsequent instalments of this series of articles to the diverse branches of modern science, engineering, and metallurgy, with which the successful sheet-mill operator must be concerned in this "mere flattening out" described by Senator Walsh.

As introductory to the general subject the following items are taken up in this article, viz.: (1) Compositions used for sheet rolling; (2) kinds and grades of sheet; (3) sizes, gauges, and tolerances; and (4) sheet tempers. That is, the present article is concerned with a description of the products made as semi-finished manufactures by the sheet-rolling mill.

Compositions Used for Sheet Rolling.

As has been intimated above, both commercially pure aluminium and various aluminium alloys are rolled into sheet. The term "commercially pure aluminium" is an indefinite one, often applied indiscriminately to various grades of aluminium. It is ordinarily used by metallurgists to connote 99+% metal, containing less than 99.5% aluminium. Aluminium alloys for sheet are divided into two main classes—viz., (1) non-heat-treatable and (2) heat-treatable. The term heat-treatable is here meant to apply to compositions that are quenched from an elevated temperature and then aged to improve their mechanical properties.

Aluminium.—Commercial aluminium sheet ordinarily contains 99% minimum aluminium. The chief impurities are copper, iron, and silicon, or iron and silicon, the percentages and kinds of impurities depending upon the source and grade of the pig metal used for the production of rolling ingots. In passing, it may be pointed out that primary 99+% aluminium as sold by the Aluminium Co. of America usually contains copper in quantities from traces to, say, 0.15%. The corresponding grade of metal sold by European producers normally contains no copper. Also, generally speaking, the aluminium content of European metal (so-called 99+% grade) is higher and the content of impurities lower than the American. This refers to metal sold to consumers. Any producer is, of course, capable of making, and does make, as good metal as any other producer. Sheet containing 98% minimum aluminium is acceptable as good delivery under some specifications, but under others 99% minimum aluminium is demanded. Ordinary commercial 99.4% aluminium sheet may contain 0.0 to 0.15% copper, 0.15 to 0.35% silicon, and 0.30 to 0.45% iron. Minor percentages of manganese, zinc, and other impurities may be present. The question of specifications will be discussed in a later article.

Taking it by and large, most consumers of aluminium sheet—i.e., manufacturers of articles from such sheet—are

⁷ Numbers pertain to references listed in the appended bibliography.

⁸ Congressional Record—Senate, vol. 72, Feb. 17, 1930, p. 3,916.

more concerned with the behaviour of the material in their particular fabricating operations—*e.g.*, drawing, stamping, bending, spinning, and other forming—than with the chemical composition or mechanical properties. That is to say, the ordinary consumer demands that the mill furnish sheet which will "work" satisfactorily in his processes. This is an unfortunate situation. Of course, in numerous cases, particularly with heat-treated aluminium-alloy sheet, the questions of chemical composition and mechanical properties assume first-rate importance, and consumers are often too finicking about these matters. In the case of commercial aluminium sheet, the mechanical properties and behaviour in working of a given grade and temper depend in part upon the chemical composition, and in part upon the specific details of the manufacturing operations in the rolling mill. So long as consumers ignore composition and properties and have no technical specifications, demanding only that the sheet will "work," many of them will continue to get inferior material at the regular prices. Since many consumers fail to appreciate the importance of specifications, and believe that "aluminium is aluminium," the sheet-mill operator may often ship rather foul compositions of metal that perform satisfactorily. This practice may be sound economics from the point of view of mill operation, but it complicates the general scrap problem in the aluminium industry, and, moreover, no part of the saving made in the use of low-grade metal is passed on to the consumer. At the same time, this unscientific method of purchasing sheet works a hardship on mill operators. Thus, sheet that may be good delivery against current specification may be found unsatisfactory by a consumer for some severe fabricating operation. Then, in order to satisfy the customer, the sheet-mill operator may be required to supply special purity metal at the regular price of ordinary sheet—or change his standard mill practice, or both.

Aluminium sheet made from ordinary commercial 99+ % metal (having impurities normal) is generally satisfactory for most purposes. The 98–99% grade is good enough for a wide variety of purposes—*e.g.*, hard sheet or material in some intermediate temper that is not to be subjected to severe deformation in fabricating and/or exposed in service to harmful corrosive media. The 99+ % grade is normally indicated for deep drawing stock and spinning, as well as some stamping and other forming operations. Generally speaking, the resistance of this grade to the action of corrosive agents is better than that of inferior (less pure) grades. For some purposes sheet made of special purity metal is required—*e.g.*, 99.5 to 99.75% aluminium minimum. Foil stock, collapsible-tube blanks, and sheet for the construction of chemical apparatus are examples of this. In American practice commercially pure aluminium sheet is known in the trade by the symbol "2S," according to the nomenclature set up by the Aluminium Co. of America. Table 1 gives some actual analyses of commercial aluminium sheet of different grades. The ratio of iron to silicon in 99+ % sheet may be controlled in some grades of sheet.

Non-heat-treatable Alloys.—Sundry aluminium alloys are rolled for sheet to be used for various purposes which require a stronger and stiffer material than aluminium, but where the special properties of the heat-treatable compositions are not necessary. Non-heat-treatable alloy sheet usually sells for about the same price as aluminium sheet, and both are considerably less expensive than duralumin. An aluminium alloy containing 1 to 1.5% manganese is rolled in large tonnage in the United States for sheet; this is referred to as 3S. The manganese content is adjusted, depending upon the properties required. Thus, two favoured compositions used for specific purposes are 1.10 and 1.25% manganese, the remainder being aluminium plus the usual impurities. The 3S alloy is used to a considerable extent in the American fabricating trade, particularly for kitchen-cooking utensils, and for many special purposes. Various aluminium-silicon alloys are rolled into sheet, both in Europe and in the United States.

These alloys contain from about 4 up to 13% silicon, and find application chiefly for manufactures where resistance to sea-water corrosion is important. An aluminium-nickel alloy containing about 1% nickel has been rolled in England and in the United States, and used where a non-heat-treatable but stronger material than aluminium is desired. This composition polishes well. A binary aluminium-chromium alloy, containing about 0.75% chromium, has been rolled in small quantities. Certain binary aluminium-copper (*e.g.*, 96 : 4 aluminium-copper) and aluminium-magnesium (*e.g.*, 96 : 4 aluminium-magnesium) alloys are rolled in subordinate tonnage. At one time an alloy having the nominal composition 97.75 : 1 : 1.25 aluminium-manganese-silicon was rolled in

TABLE 1.

SOME ANALYSES OF ALUMINIUM SHEET OF DIFFERENT GRADES.*

Grade.	Chemical Composition Elements, %.					
	Al.†	Cu.	Fe.	Si.	Mn.	Zn.
Special purity.....	99.64	nil	0.26	0.10	nil	nil
Special purity.....	99.59	0.01	0.25	0.15	nil	nil
99+ %	99.46	nil	0.36	0.18	nil	nil
99+ %	99.35	nil	0.37	0.28	nil	trace
99+ %	99.27	nil	0.43	0.30	nil	nil
98–99%	98.96	0.12	0.60	0.25	0.04	0.03
98–99%	98.85	0.15	0.61	0.31	0.06	0.02
98–99%	98.77	0.20	0.65	0.28	0.05	0.05

* Selected from numerous analyses made of commercial sheet.

† Aluminium, by difference.

the United States for the fabrication of radiator shells for the Chevrolet motor-car. The so-called "KS Seewasser" alloy, containing manganese and antimony, recommended for corrosion-resisting purposes, is now being rolled in Germany. While the alloys above-mentioned are referred to as non-heat-treatable, some of them can be heat-treated—*i.e.*, certain of the compositions are susceptible to enhancement of mechanical properties by quenching followed by heat-treatment, but are furnished in the same tempers as aluminium sheet. Table 2 lists some actual analyses of commercial aluminium-alloy sheet of the compositions given above.

TABLE 2.

SOME ANALYSES OF ALUMINIUM-ALLOY SHEET—NON-HEAT-TREATABLE TYPE.*

Nominal Composition, or Name.	Chemical Composition Elements, %.							
	Al.†	Cu.	Fe.	Mg.	Mn.	Ni.	Si.	Zn.
3S	98.14	nil	0.42	nil	1.14	nil	0.20	trace
3S	97.84	0.04	0.50	nil	1.36	nil	0.26	nil
3S	97.82	0.10	0.62	nil	1.05	nil	0.31	nil
95 : 5 aluminium-silicon	94.55	0.08	0.49	nil	0.03	nil	4.82	0.03
95 : 5 aluminium-silicon	94.36	0.02	0.56	nil	nil	nil	5.06	trace
99 : 1 aluminium-nickel	98.10	0.11	0.46	nil	0.02	1.12	0.19	nil
99.25 : 0.75 aluminium-chromium	98.49	0.06	0.51	0.66	nil	—	0.28	nil
96 : 4 aluminium-copper	95.30	4.12	0.39	nil	nil	nil	0.19	trace
96 : 4 aluminium-magnesium	95.45	0.01	0.39	3.86	0.04	nil	0.25	nil
97.75 : 1 : 1.25 aluminium-manganese-silicon	97.06	0.21	0.41	nil	1.03	nil	1.25	nil
97.75 : 1 : 1.25 aluminium-manganese-silicon	97.31	0.03	0.37	nil	1.10	nil	1.19	nil

* Selected from numerous analyses of commercial aluminium-alloy sheet.

† Aluminium, by difference.

In passing, reference should be had to some of the considerable experimental work done on the rolling of various aluminium alloys into sheet with the object of securing better mechanical properties than are available with aluminium sheet. This refers more especially to alloys of the non-heat-treatable type. Thus, Carpenter and Edwards¹ have reported work on the rolling of binary aluminium-copper alloys containing up to about 5% copper.

Several binary aluminium-zinc alloys and the 72:3:25 aluminium-copper-zinc alloy have been rolled into sheet by Rosenhain and Archbutt². Schirmeister³ has shown experimentally that many binary alloys of aluminium can be rolled into sheet. The range of compositions that he found amenable to rolling includes the following:—Binary alloys of aluminium with antimony up to 10.5%; with bismuth up to 4.8%; cadmium up to 6%; chromium up to 4.5%; cobalt up to 12%; copper up to 11%; iron up to 12.5%; lead up to 4%; magnesium up to 6%; manganese up to 4.8%; molybdenum up to 4.9%; nickel up to 10.3%; silicon up to 18.8%; tantalum up to 3.5%; tin up to 12.4%; titanium up to 6.2%; tungsten up to 6%; vanadium up to 3.7%; zinc up to 25.3%; and with zirconium up to 6%. Data are reported by Rosenhain, Archbutt, and Hanson⁹ on the rolling of the 77:3:20 aluminium-copper-zinc alloy and several variations thereof. Experiments have also been made by Schulte⁸. Considerable information has been reported in the literature regarding the rolling of aluminium alloys into bars and rods, but this matter need not be taken up here.

Heat-treatable Alloys.—Turning now to heat-treatable aluminium alloys for sheet production, it may be said that while much experimental work has been done with a view to securing better alloys than duralumin, or for the purpose of getting around existing patent claims, and while a considerable list of special alloys has been placed on the

aluminium and certain alloys (non-heat-treatable and heat-treatable) are also used for forgings and rolled and extruded shapes, including tubes.

The chief heat-treatable alloys used in practice for sheet production include three main classes—viz., the copper-aluminide (CuAl_2) type, (2) the magnesium-silicide (Mg_2Si) type, and (3) the copper aluminide-magnesium-silicide type. These are so called because the intermetallic compounds mentioned are responsible for the heat-treating effects. A typical example of the copper-aluminide type is the alloy 25 S, produced by the Aluminium Co. of America. The nominal composition of this alloy, as well as those of other heat-treatable alloys used for sheet rolling, is given in Table 3. As contrasted with the other two types of heat-treatable compositions, the copper-aluminide type, for practical purposes, does not age-harden spontaneously at the ordinary temperature after quenching. In order to develop the desired mechanical properties in these alloys, it is necessary to heat for a considerable period of time at some moderately elevated temperature (120° to 160° C.) after quenching. The theoretical aspects of the heat-treatment of aluminium alloys will be discussed at some length in a later article. Other trade compositions of the copper-aluminide type include so called Lantal, Aeron, and L. M. (this latter being the French variant of 25 S). There are sundry heat-treatable alloys of the pseudo-binary aluminium-magnesium silicide type. A typical alloy of this class is that known as 51 S, manufactured by the Aluminium Co. of America (cf. Table 3). Similar compositions are rolled for sheet in several European countries, and a special composition of this class is used for the production of cables for power transmission—the so-called Aldrey alloy, developed in Switzerland. These alloys are self-hardening, but higher strength can be obtained by artificial ageing. The tensile strength obtainable with alloys of this type by heat-treatment is not so high as with the copper-aluminide or duralumin types. The aluminium-magnesium-silicide alloys are rolled more easily, with less scrap loss, than alloys of the other two types. Alloys of the combined copper-aluminide and magnesium-silicide type are very numerous, duralumin being the parent composition. Most of the others have been derived by some variation in the original composition of duralumin. By duralumin is usually understood an alloy containing 3.5 to 4.5% copper, 0.4 to 1% manganese, 0.3 to 0.75% magnesium, and the remainder aluminium (plus the usual impurities). The presence of the impurity silicon is essential. Among commercial alloys of the duralumin class there may be mentioned the following: 17 S, A17 S, B17 S, C17 S (manufactured by the Aluminium Co. of America), Aldal, Almag, Alferium, Aeral, Avional, Koltchougumin, Y alloy, and super-duralumin. Alloys of the combined copper-aluminide and magnesium-silicide type age-harden spontaneously in the air after quenching. The best combination of mechanical properties in ordinary duralumin is obtained by quenching followed by air-ageing. These alloys may also be subjected to artificial ageing to enhance the properties. Table 3 gives the nominal composition of a list of heat-treatable aluminium alloys rolled into sheet. When fully heat-treated—i.e., quenched and aged at moderately elevated temperature—rolled alloys of the copper-aluminide type yield tensile strength of 54,000 to 62,000 lb. per sq. in., yield point of 30,000 to 40,000 lb., and elongation of 16 to 24%. Magnesium-silicide alloys in sheet form when quenched and air-aged have tensile strength of about 30,000 to 40,000 lb., yield point of 15,000 to 20,000 lb., and elongation of 20 to 30%; when quenched and aged at moderately elevated temperature, the tensile strength is 45,000 to 50,000 lb., yield point 30,000 to 40,000 lb., and elongation 8 to 18%. Alloys of the duralumin type, heat-treated so as to acquire maximum strength, have tensile strength of 56,000 to 75,000 lb., yield point of 30,000 to 50,000 lb., and elongation of 10 to 20%. These values may be compared with 12,000 lb. tensile strength

TABLE 3.
NOMINAL COMPOSITIONS OF ALUMINIUM ALLOYS FOR SHEET—
HEAT-TREATABLE TYPE.

Name or Symbol.	Chemical Composition Elements, %.						
	Cu.	Fe.	Mg.	Mn.	Ni.	Si.	Other Elements.
COPPER-ALUMINIDE TYPE.							
25 S	3.9-5.0*	•	—	0.5-1.1	—	0.5-1.1	—
Lantal	4	•	—	—	—	2	—
L. M.	4-7.5	•	—	0-7.5	—	0-7.5	—
MAGNESIUM-SILICIDE TYPE.							
51 S	—	•	0.45-0.80	—	—	0.6-1.2	—
Almasilium ..	—	•	1	—	—	2	—
Aldrey	—	•	0-4	—	—	0-6	—
Montegal	—	•	0-9.5	—	—	0-8	0.2 Ca.
DURALUMIN TYPE.							
Duralumin ...	3.5-4.5	•	0.3-0.75	0.4-1	—	•	—
17 S	4	•	0-5	0-5	—	•	—
A17 S	2-5	•	0-3	—	—	•	—
B17 S	3-5	•	0-3	—	—	•	—
C17 S	4	•	0-5	0-5	—	1-2.5	—
Super-dural'min	4-5	•	0-4	0-8	—	0-8	—
Almag	2-5	•	0-7	—	—	0-6	—
Aeral	3-5	•	1-8	—	—	0-6	2-25Cd
Y alloy	4	•	1-5	—	2	•	—

* Impurity (iron or silicon) normal.

market, the bulk of present industrial requirements can readily be met with a relatively few compositions. The mechanical properties of duralumin have been but little improved upon despite all the experimental work that has been done. If there were no other strong alloy available for sheet except duralumin, consumers could manage to get along very nicely. In American practice the great bulk of sheet production is in 2 S, with 3 S standing second in tonnage output, and duralumin third. In Europe aluminium is the chief sheet material, with duralumin second. In both the United States and Europe the other alloys make up a minor percentage of the tonnage rolled, but more different kinds of alloys are rolled into sheet in Europe than in America. While the total output of both standard and heat-treatable aluminium alloys, other than duralumin, has been comparatively small, it appears that the consumption of both may be expected to increase substantially. In passing, it may be pointed out that both

and 30% elongation for soft-annealed aluminium sheet, and 22,000 to 30,000 lb. tensile strength, and 4 to 1% elongation for full-hard aluminium sheet.

Some other alloys that fall in none of the above-mentioned classes have been marketed for sheet—*e.g.*, so called Scleron and Constructal. In one of the Scleron compositions lithium is used as a substitute for magnesium; this element forms lithium silicide (Li_2Si), which acts as an age-hardening agent. The alloy known as Constructal 8 contains the compound MgZn_2 as the hardening agent. These alloys were developed in Germany. In experimental work on alloys of the duralumin type, compositions in the range 0 to 3.5% magnesium, 0.02 to 3.22% copper, 0 to 1.68% manganese, 0 to 3.94% nickel, 0.26 to 0.76% iron, 0.13 to 0.39% silicon, and remainder aluminium were rolled into sheet by Merica, Waltenberg, and Finn⁵. In other work, Merica, Waltenberg, and Scott⁶ report the rolling of alloys in the range of 0.4 to 3.74% copper, 0 to 3.5% magnesium, 0.27 to 0.62% iron, 0.18 to 0.34% silicon, and remainder aluminium. Mention should be made here of the composite material known as Alclad, used mainly in sheet form. This consists of duralumin coated with a thin layer of pure (Hoopes) aluminium. Recently, the commercial production of aluminium-coated steel sheets has been started.

Kinds and Grades of Sheet.

Aluminium and aluminium-alloy sheet are produced by rolling mills in various grades, sizes, gauges, tempers, and surface finishes to meet the diverse requirements of consumers in the stamping, fabricating, and speciality-manufacturing trades. The term sheet is used here to apply to the products made by rolling aluminium or its alloys into flats or coils, the width, as rolled, being usually in excess of 8 in. Fairly wide bar stock—*e.g.*, bus bars—is also rolled; but this is not classed with sheet. The principal kinds of aluminium sheet made here have been discussed by the writer¹² in another place. Both aluminium and aluminium-alloy sheet are taken up in the present article.

There are two main classes of sheet, viz.—(1) flat sheet, and (2) strip sheet. Flat sheet is a product of the flat-sheet mill; it is made in a wide variety of sizes, often in rather large sizes. Strip sheet is a product of the strip or coil mill; it is usually rolled in long lengths and rather narrow widths. This product is wound into coils as it comes off the mill, on account of the long lengths, and hence it is usually referred to as coiled sheet or coils. In the case of flat sheet there are two main kinds of surface finishes produced—viz., (1) bright finish, and (2) grey finish. Products having these finishes are termed "bright flat sheet" and "grey plate." Grey plate is usually rolled in rather heavy gauges, whereas bright flat sheet is rolled in all gauges.

Following is a list of the principal kinds of sheet made by the rolling mill:—

1. Plate.
2. Bright flat sheet.
3. Extra-bright flat sheet (mirror finish).
4. Grey plate.
5. Coiled sheet (strip sheet, coils).
6. Strips, flat and coiled.
7. Circles (cut from bright flat sheet, grey plate, or sheet).
8. Flattened coil.
9. Radio sheet.
10. Lithographic plate.
11. Collapsible tube stock.
12. Foil stock.

Plate is heavy sheet, material heavier than $\frac{1}{8}$ in. thick ordinarily being put in the plate category. Such material is made of aluminium or alloys, but usually of 99+ % metal. It is usually rolled on flat-sheet mills, although narrow plate may be run on coil mills. Plate is sawed to size. Bright flat sheet is a product of the flat-sheet mill. The surface is planished, the rolling being done on highly polished rolls; buffs, contacting with the rolls, help to maintain the polished surface during rolling. Generally speaking, a bright surface finish is more readily imparted

to aluminium than to the various alloys by rolling. Extra-bright flat sheet (mirror finish) is made on flat-sheet mill using highly polished rolls. The extra-bright finish is obtained by increasing the normal number of finishing passes, or such a finish may be imparted by polishing bright flat sheet on a special polishing machine. Grey plate is also a product of the flat-sheet mill; the surface finish is dark grey in appearance. This product is made by rolling with coated rolls. A coating consisting of a mixture of fine particles of aluminium and aluminium oxide forms on rolls when aluminium is rolled in a mill not equipped with buffs. Coiled sheet is made on continuous strip mills, tandem mills, or single-strand coil mills. The surface appearance is roughly midway between that of bright flat sheet and grey plate, the rolling being done with oil, so that a high finish, like that on planished sheet, is not obtained. Both aluminium and various alloys are rolled into coil. Coiled sheet shows slight surface flow lines in the direction of rolling. However, such lines are readily polished out on buffing. Both bright flat sheet and grey plate are sometimes stretched in so-called sheet stretchers or levelling machines, for the purpose of "ironing out" any slight buckles or waves and producing sheet that will lie substantially flat. Such sheet is called stretched sheet. Strips of various widths and lengths are made by the shearing of flat sheet. Coiled strips are made by the slitting of coiled sheet. Circles may be cut on circle shears from squares that have previously been sheared from sheet or coil, or circles may be blanked on presses from strips or coiled sheet. Strips known as flattened coil are made by shearing lengths from coil, followed by flattening in a roll leveller. Radio sheet is bright flat sheet, often sheared into narrow strips; the gauge tolerance is very close. Lithographic plate is a special grade of bright flat sheet made with considerable cross rolling; the gauge tolerance is close. Collapsible-tube stock consists either of narrow strips or disc blanks, in rather heavy gauges, made of special purity metal. Foil stock is coiled sheet in narrow to medium widths, made of special purity metal.

Plate, bright flat sheet, grey plate, coils, strips, circles, and flattened coil are produced in aluminium and various alloys, according to requirements. The items, 9 to 12 inclusive, listed above are not made in alloys. Aluminium and aluminium-alloy sheet products are supplied in special surface finishes as required, *e.g.*, polished, satin finished, or scratch brushed, and matte or dip finish. Special surface finishes carry certain differential extras. The prices charged for the different kinds and grades of aluminium and aluminium-alloy sheet necessarily vary, depending upon the grade, quantity, and size. Consumers may often save money by communicating with producers regarding the uses to which sheet products are to be put, since the producer may be able to suggest a less-expensive grade that will be quite satisfactory for the purpose intended.

(To be continued.)

Ascertaining the Geological Structure of the Earth's Strata.

A decision of considerable importance has recently been given by the German Reich Court. The case in connection with this decision arose out of an attack upon Professor Dr. Ludger Mintrop's patent, which covered a process for ascertaining the geological structure of strata, the main characteristic of which is the artificial production of elastic waves by creating an explosion, then obtaining a seismogram by means of a seismograph erected at a suitable distance, and ascertaining therefrom the speeds of the elastic waves and the depth which they have reached.

The attack upon the patent was based upon the earlier researches of Wiechert and Wilip, who seemed to have realised that a seismograph was possibly useful for practical purposes in connection with mining. The Reich Court, however, came to the conclusion that Professor Dr. Mintrop's method of utilising the Wiechert earthquake calculation was surprising, and by no means obvious.

The Modern Blast Furnace and its Operation

By R. A. Hacking, M.Sc.

PART V.

Use of oxygen-enriched blast—Theoretical considerations—Future possibilities—
Effect of increased blast pressure—Influence of increased blast velocity—
Practical considerations.

IT has been shown that two of the main factors determining the temperature of the "Combustion Zone" opposite each tuyère, for a given rate of heat input, are as follows:—

(a) The number of thermal units carried off by the gaseous products of combustion.

(b) The volume of the zone.

The magnitude of both items (a) and (b) is decreased by the use of oxygen-enriched blast, instead of natural air. This is readily explained by the following considerations:—

(1.) The nitrogen of the blast performs no useful chemical function in the "Combustion Zone"—being involved in secondary reactions only,—and may be regarded as functioning only as a diluent in both incoming and outgoing gases. Even with the highest blast temperatures attainable, the nitrogen obviously enters the zone at a much lower temperature than it leaves, and its specific heat at any given temperature is the same as that of carbon monoxide. Thus the nitrogen of the blast lowers the temperature of the "Combustion Zone" by carrying heat units up into the shaft, a function which led to its being called the "heat carrier" by observers of the nineteenth century. The use of oxygen-enriched blast reduces the amount of diluent nitrogen entering the furnace per pound of carbon oxidised at the tuyères, thus resulting in a considerable increase in the temperature of the "Combustion Zone."

Incidentally, the weight of blast entering the furnace per pound of carbon burnt and per pound of pig iron made is decreased, thus providing a further example of the tendency towards "low wind" which has characterised every forward step in fuel economy since the origin of the blast furnace.

(2.) By raising the oxygen content of the blast the opportunity for direct collision of oxygen and carbon molecules is increased, since the proportion of diluent nitrogen is decreased. Reaction is therefore accelerated, and the volume of the "Combustion Zone" decreased, with a corresponding increase in the temperature obtaining there.

(3.) With a given total blast pressure, oxygen enrichment increases the partial pressure of that element, and reaction is accelerated accordingly. The effect of pressure is dealt with in the next section.

The theoretical effect of item (1) may be readily calculated. The relation between the theoretical temperature of combustion of pure carbon oxidised to carbon monoxide, and the oxygen content of the blast, is shown in the graph in Fig. 5. As before, the specific heats and heats of formation used in the calculations are those given by Richards.

It will be seen from the diagram that each one-per-cent. increase by weight in the oxygen content of the blast raises the theoretical temperature of combustion by approximately 125° F. With a given blast temperature of, say, 1,000° F., this figure would be somewhat lower, on account of the smaller number of B.th.u.s brought in by the reduced weight of blast per pound of carbon oxidised at the tuyères. However, since the advocates of the use of oxygen-enriched blast have hitherto counted the saving of the capital cost

of the stoves as one of its main advantages, the use of cold blast has been assumed throughout the calculations.

On this theoretical basis, therefore, it may be stated, in regard to the air blast, that an increase in oxygen content of one per cent. by weight is equivalent to an increase in blast temperature of approximately 150° F., or to a reduction in moisture content of 5 grains per cubic foot.

Thus, oxygen enrichment of the blast may be regarded as a very effective agent towards the attainment of "heat compression" and fuel economy. Further, suitable means for varying the oxygen content of the blast would provide the operator with a useful method for controlling the condition of his furnace.

Future Possibilities.

The use of super-oxygenated air in the blast furnace, and in metallurgical processes generally, has been the subject of much discussion during the past few years.

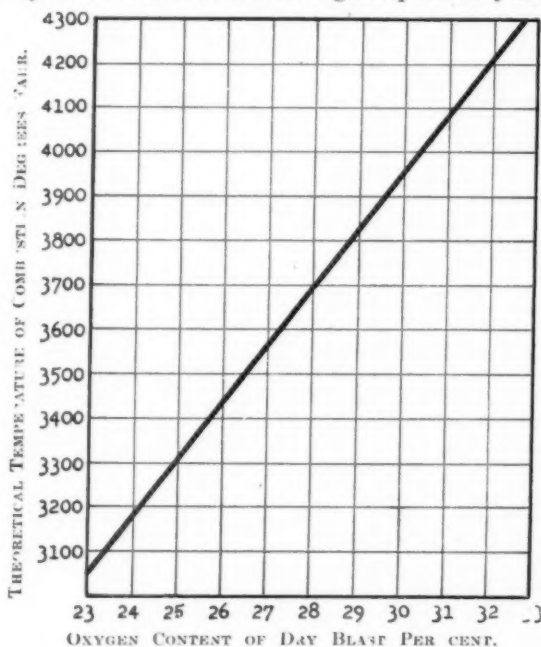


Fig. 5.—Relation between Oxygen Content of Blast, and Theoretical Temperature of Combustion of Pure Carbon, according to C. O.

It appears that at least one application of the principle to actual practice has been made on a blast furnace at Liège in Belgium. It is stated that enrichment up to 25 per cent. of oxygen enabled the stoves to be dispensed with, and a higher grade of pig iron to be produced. Other technical results of the trial are in agreement with theoretical considerations, but no information appears to be available regarding the commercial success, or otherwise, of the venture.

A committee formed under the auspices of the United States Bureau of Mines published in 1924 a report of an extensive investigation into the subject (American Institute of Mining and Metallurgical Engineers, Pamphlet

No. 1,377-8). Table 3, which is taken from this report, shows the estimated thermal advantage of oxygen enrichment of the blast on a coke blast furnace.

It is recommended in the report that the blast should be enriched so as to contain 31 per cent. of oxygen, and that it should enter the furnace at atmospheric temperature. Under these circumstances an increase in production

TABLE 3.
THERMAL EFFECT OF OXYGEN ENRICHMENT OF BLAST.

Analysis of Blast by Weight, %.		Temperature of Blast, ° F.	Temperature Available at Tuyères, ° F.	Hearth Heat Available Above 2740° F. B.th.u.	Increase %.
Natural air		720	3,483	102,711	
Oxygen, %.	Nitrogen, %.				
30	70	Atmospheric	3,360	124,855	21
40	60	"	4,032	188,589	83
50	50	"	4,613	226,945	121
60	40	"	5,099	254,492	145
70	30	"	5,530	270,792	163
80	20	"	5,891	284,481	177
90	10	"	6,215	295,168	187
100	0	"	6,505	303,659	195

of 18 per cent. is estimated. The capital cost and running and maintenance charges of the stoves would be saved. Progress along these lines would eventually lead to inadequate thermal preparation of the charge in the shaft, which could be overcome to some extent by using calcined ore, burnt lime, etc. Such changes would ultimately necessitate alterations in furnace design.

At the present time, however, the application of oxygen-enriched blast is not a commercial proposition, since no process is available for producing oxygen at a price which would be covered by the resultant economies in the furnace practice. Should such a process be devised as a result of the research work at present in progress, the pig-iron blast furnace offers wide scope for its application.

Effect of Increased Blast Pressure.

Korevaar ("Combustion in the Gas Producer and the Blast Furnace") has shown that with a given coke, blast temperature, and rate of blowing, the speed of reaction in the "Combustion Zone" is dependent upon the partial pressure of the oxygen in the blast. This point has been referred to in the section on oxygen enrichment. However, if natural air only is used, the partial pressure of the oxygen may be raised by increasing the total pressure in the furnace hearth. Clements ("Blast Furnace Practice," vols. 1 and 2) has calculated the pressure drop through the tuyères for a large number of furnaces, and quotes a range of 0.3376 to 1.922, with an average of approximately 0.86 lb. per square inch. Thus, the pressure in the furnace hearth has a closer relationship to the recorded pressure in the blast main than is generally supposed.

It follows that the concentration of heat in the hearth of the furnace should be facilitated by the use of increased blast pressure. This factor is governed largely by the nature of the burden, and ranges from 5 lb. per square inch on British furnaces smelting low-grade domestic ores, up to 20 to 25 lb. per square inch on some of the large modern units in Europe and the United States, where rich fine or graded ores constitute the bulk of the burden.

Influence of Increased Blast Velocity.

In hot-blast stove design the importance of the velocity of gases in promoting heat transfer is well established. When a fluid such as a gas is in contact with a solid, a relatively stationary film of fluid adheres to the surface of the solid. High gas velocities tend to diminish the thickness of this adherent non-conducting film, thus increasing the rate of heat transfer between solid and fluid.

The same principle is applicable apparently to the "Combustion Zone" of the blast furnace, but in this case rate of chemical reaction and not speed of heat transfer is the main consideration. Thus, by diminishing the thickness of the relatively inactive fluid film adhering to each carbon surface, a high blast velocity should tend to speed up reaction and increase the temperature obtaining in the zone.

Practical Considerations.

Kinney (United States Bureau of Mines) has investigated the effects of varying blast pressure and velocity on the dimensions of the "Combustion Zone" in a furnace of 13 ft. 6 in. hearth diameter and an output of 314 tons of basic pig iron per day. The zone was explored by means of gas analyses, with blast pressures of 14 lb. and 1 lb. per square inch respectively. The results indicated that varying blast pressure and blast velocity have very little influence on the shape and size of the "Combustion Zone" in front of each tuyère.

At the same time it appears that those furnaces which employ high blast pressures and velocities attain a high degree of "heat compression," which is reflected in low fuel consumption per ton of pig iron. It is impossible, however, rigidly to connect cause and effect in this instance, on account of the innumerable variables in blast-furnace operation and the complicated phenomena of the process. For example, the apparent economy of furnaces using high blast pressures may be due more to the influence of pressure upon the breakdown of carbon monoxide in the shaft, rather than to its influence upon the combustion of carbon in the hearth.

Most British blast-furnace operators use the "constant-volume" method of blowing, and prefer to see their furnaces taking the predetermined volume of blast at a low blast pressure. The author has personal experience of several British furnaces which apparently give the best results under these conditions. This appears to disagree with the foregoing speculations. With a given rate of blowing, however, the most suitable blast pressure is determined mainly by the nature of the charge. The ungraded burdens which are the general rule in Great Britain at present, undoubtedly work best on relatively low blast pressures. With "constant-volume" blowing any sharp unexplained rise in blast pressure is regarded with alarm, since a short spell of intermittent working due to "hanging" and "slipping" is sufficient to spoil a whole month's cost sheet. Thus, the benefits of the use of high blast pressures are not likely to be realised on many British furnaces until crushing and grading of ore, flux, and fuel are extensively adopted.

In the same way the velocity of the air blast through the tuyères is largely determined by other factors, and is frequently modified to correct intermittent descent of the charge, erosion of brickwork, inadequate penetration, weak tapping holes, etc.

There is at present on the market at least one design of tuyère in which the Venturi principle is used to increase the velocity of the blast as it enters the "Combustion Zone." No information is yet available as to the results obtained with this device.

(To be continued.)

Imported Electricity Meters and Parts.

The Standing Committee appointed by the Board of Trade will hold an inquiry under the Merchandise Marks Act, at 11.30 a.m. on Monday, October 20, and at 10.30 a.m. on Tuesday, October 21, as to whether imported goods of the following descriptions should be required to bear an indication of origin:—(a) Electricity meters which register by integration over a period of time the consumption or quantity of electricity used in any electric circuit; and (b) the following parts of such meters—namely, the case, the rotor, the shunt system, and the series system. The inquiry will be held at the Board of Trade Offices, Great George Street, S.W. 1. Communications should be addressed to the secretary, Mr. E. W. Reardon, at that address.

Modern Practice in the Cold Rolling of Non-Ferrous Metals*

By C. E. Davies, A.M.I.Mech.E.

The Economic Value of Higher Rolling Speeds

INCREASED production per mill, other conditions remaining unaltered, can be obtained by increasing rolling speeds, and, as previously explained, the speed of rolling in America has been for many years considerably higher than that usually worked in this country.

Also to be economically advantageous any increase in speed of rolls must not involve a greater power of consumption per ton of metal rolled, or a relative increase in labour cost.

Old practice in the States obtained higher speeds to some extent at the expense of power, and earlier attempts at high-speed rolling in England were only partly successful.

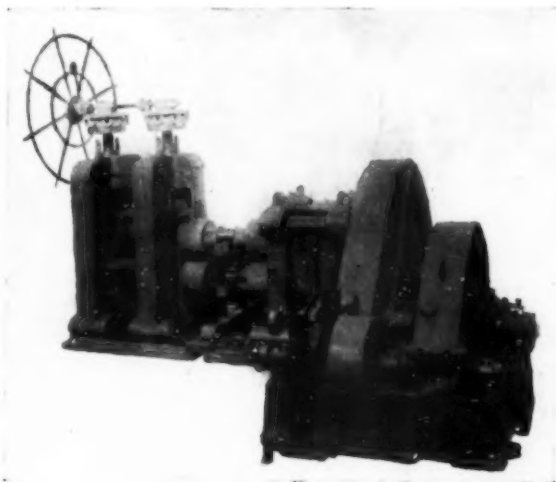


Fig. 2.—Breaking-down Mill.

owing to the relatively greater power required to drive a pair of rolls at the higher speed on any given reduction, and the opinion was held, and is still held by many, that the resistance of the metal to deformation increased with increasing speeds, and that high-speed mills were inherently wasteful of power. This has, however, now proved to be incorrect, and also that the loss of power with increased rolling speeds is entirely due to frictional losses in the roll bearings.

With the old type of mill, even of the best type, with accurately fitted bearings, at least 40% of the total power was lost in roll-bearing friction, and with increasing speed this loss becomes more and more serious, causing excessive heating of bearings and rolls, which again increases frictional losses and further waste of power. Incidentally, the irregular heating of rolls and bearings was detrimental to accuracy.

For several years recently rolling-mill engineers have endeavoured to overcome the trouble, and by the use of roller bearings or improved lubrication systems for bearings of the plain metal type, success has been obtained; and now the latest high-speed mills are actually more efficient, mechanically, in that the power consumption per ton of metal rolled is actually less than with the older slow-speed mills.

As increased rolling speed is more advantageous for the finishing passes, especially when rolling thin metal, it is natural that the highest speeds have been adopted for finishing mills; and whilst it is desirable to operate any mill at the highest practical speed, there is not so great a necessity for higher speeds with breaking-down and roughing mills.

Breaking-down mills are therefore very rarely designed to work at more than 5 to 80 f.p.m., mainly because at these speeds one breaking-down mill will supply the needs of a very large installation of finishing mills.

An example of modern cold breaking-down mill, by W. H. A. Robertson and Co., Ltd., of Bedford, is shown by Fig. 2. This mill has rolls 24 in. diameter, 32 in. face, driven by machine-cut gearing from a 250-h.p. motor, and is capable of the heaviest reductions on wide ingots at the moderate speeds mentioned. The roll frames are exceptionally strong and rigid to eliminate "stretch," and the adjustment of top roll is effected by means of a large hand-wheel operating both pressure screws through gearing.

Although, so far, only comparatively low speeds are preferred in the breaking-down mill, the writer is of the opinion that before long speeds of 100 to 200 f.p.m. will be quite usual. A mill of this type has already been installed with 22-in. diameter rolls of hardened steel for cold rolling of strip steel, which is fitted with patent "Flood" lubrication roll bearings and lubrication system, which is successfully working at a speed of 250 f.p.m.

Intermediate Mills.

These are necessary for getting down prior to finishing. For reducing strip metal from $\frac{1}{2}$ in. thick to gauges as required for further finishing the modern powerful high-speed mill has exceptional advantages, and a good example of these mills is shown by Fig. 3. The mill illustrated here has steel rolls, 14 in. diameter, 18 in. face, and is now usually operated at rolling speeds from 150 to 200 f.p.m., although there is no difficulty in working at 250 f.p.m., or even faster. The mill is direct driven by a 150-h.p. motor, and is equipped with patent "Flood" lubrication roll bearings. Automatic-coiling equipment is provided in duplicate. The "Hine" type or roll coiler for thick metal



Fig. 3.—14 in. x 18 in. Mill.

from $\frac{1}{16}$ in. thick down to $\frac{3}{16}$ in., mounted on hinged bracket, so that it may be swung clear when not required, and a "Tormanco" automatic strip coiler for lighter gauges. This mill is capable of economical reduction in metal up to 14 in. wide.

*(Continued from page 146 in the August issue.)

Finishing Mills.

High-speed mills again are most economical for finishing work, and the economy obtained by high-speed rolling when finishing thin metal is very considerable. The size of the rolls employed depends on width of metal rolled; for wider metal, 12 in. to 16 in. wide, exactly similar mills

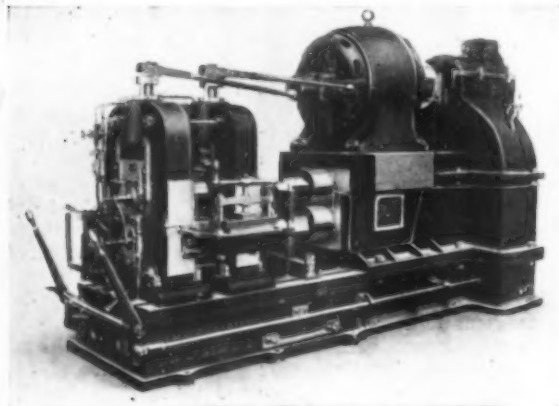


Fig. 5.—10 in. High-speed A. i. l.

to that illustrated by Fig. 3, and described above, are employed, with rolls 14 in. diameter, 18 in. or 20 in. face width, and even larger mills have recently been installed, as shown by Fig. 4, which illustrates a mill with 16-in. diameter rolls. With patent "Flood" lubrication bearings these mills are operated at speeds of 150 ft. to 200 ft.

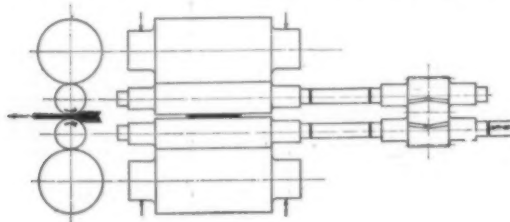


Fig. 7.

per min., and owing to the exceptional rigidity of the design, heavy reductions, 33% to 40% per pass, are taken, and the accuracy attained is of the highest order. The minimum thickness usually finished on these mills with rolls about 14 in. diameter is 0.010, but strip as thin as 0.005 can easily be produced. For narrower metal smaller rolls running at higher speeds are now installed, and the most popular mills are those with rolls 12 in. diameter, 14 in. to 16 in. wide for metal up to, say, 10 in. wide and 10 in. diameter, 10 in. to 12 in. face for metal up to 7 in. wide.

Many of these smaller high-speed finishing mills are now working in this country at 250 f.p.m. rolling speed, and only recently a new design has been developed and is in regular service with a rolling speed of 300 f.p.m. This mill is illustrated by Fig. 5. The rolls are, of course, of hardened steel, internally water cooled, and running in "Flood" lubrication bearings. The driving gear is totally enclosed in an oil-tight gear-case, with machine-cut double-helical gearing, and shaft running in roller bearings. The motor is mounted above gear-case, making an entirely self-contained machine, occupying the minimum of floor space. 12-in. finishing mills at 250 f.p.m. are usually driven by motors of about 90 h.p., and 10-in. mills at 300 f.p.m. by 70 h.p. motors. This latter size is most efficient on light gauge from 0.010 in. to 0.003 in. thick, 6 in. to 7 in. wide, taking reductions of 40% to 45% per pass.

A 10-in. mill at 300 f.p.m. can finish as much as $6\frac{1}{4}$ tons of strip, $6\frac{1}{4}$ in. wide, from 0.0075 to 0.005 thick (one pass), in 8 hours. It is, of course, essential that these high-duty mills should be equipped with the improved roll bearings and lubrication system, and the patent "Flood" lubrication bearings, as fitted to the mills already described, have proved their success in remaining cool at the exceptionally high speeds and with the heavy roll pressures necessary to effect the reduction specified.

It is remarkable that whilst a few years ago there were no mills in British non-ferrous metal mills operating at speeds higher than 80 f.p.m., 250 and 300 f.p.m. are becoming quite common; in fact, it is probable that new mills installed during the next year or two will be working at 400 f.p.m. There is certainly now no practical difficulty in this further increase of speed. The economical gain is very clear, in so much that a modern high-speed mill has a productive capacity from three to four times that of the best type of slow-speed mill.

To handle the metal at these high speeds some automatic coiling equipment is necessary, and the best of these is that now built in this country to the designs of the Torrington Manufacturing Co., Torrington, Connecticut, U.S.A., which is in general use in most of the leading brass mills in the States. The double-spindle design has two drums which are in action alternately, so that the finished coil can be removed from one whilst the other is coiling, thereby reducing lost time to a minimum. This design is fitted to the high-speed finishing mills described, and enables a rolling efficiency of 75% to 80% to be attained under normal mill conditions.

Rolling efficiency expresses the ratio of the actual length of strip rolled in a given time, to the maximum

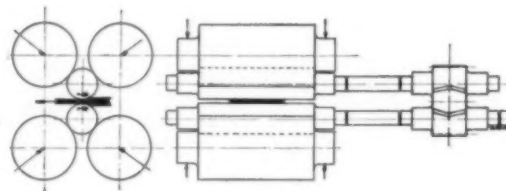


Fig. 8.

possible that is based on the peripheral velocity of the rolls.

To sum up the essentials of a modern brass strip-finishing mill:—

- (1) It must be capable of effecting reductions per pass of from 33% to 45% on metal of the full width with which the rolls will conveniently deal.
- (2) The rolling speed must be the highest possible consistent with convenient handling.

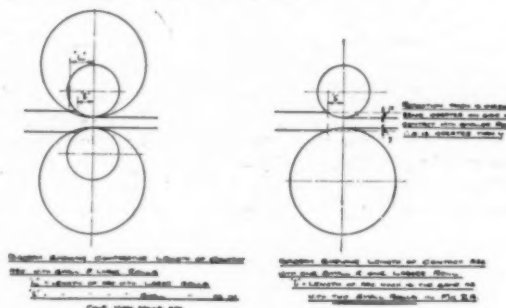


Fig. 6.

- (3) The accuracy and uniformity of thickness must be within the finest limits as now required by the purchaser of metal.

(4) The power consumption per ton rolled must be the minimum possible, and less than that taken by the old slow-speed mills.

These exacting conditions are fulfilled by the mills that have been described, and with the increasing popularity of these designs the rolling cost of cold-rolled brass strip should eventually be reduced by 50% at least.

Whilst the foregoing outlines the very considerable development of the modern two-high mill, giving increased production and reduced power cost, the second important advance recently made is the introduction of the "backed-up roll mill," of which there are two important varieties, viz., the "Cluster," or six-roll mill, and the "Four-high." Both types claim advantages due to the same principle, which is the use of a *small-diameter* working roll, which is supported against flexure under load by two, or in the case of the cluster design four, larger rolls, which latter are not driven but are worked by frictional contact with the working rolls. Usually these support rolls are carried in roller bearings. The practical advantage in using a small-diameter working roll is, as will be easily understood, the small area of contact, and consequently decreased pressure necessary to effect any given reduction. This will be explained by the diagram Fig. 6; Figs. 7 and 8 show in outline the arrangement of rolls in the cluster and four-high designs.

The cluster mill has the advantage that the working rolls are supported in two directions by the four supporting rolls, and are self-aligned, each backing roll carrying, owing to the angular directions of support, about 70% of the total load. The working rolls require only locating bearings. The four-high mill, on the other hand, is simpler, and is probably more rigid in construction. In this design adjustable bearings are required to hold the working rolls in position horizontally, but whilst this side adjustment is necessary it is a comparatively simple matter to correct any misalignment due to wear, and the adjustment is

Another advantage claimed for these mills is reduced power consumption, this being due to the possibility of employing roller bearings of sufficient size; but actually, as regards power economy, these designs do not in the smaller

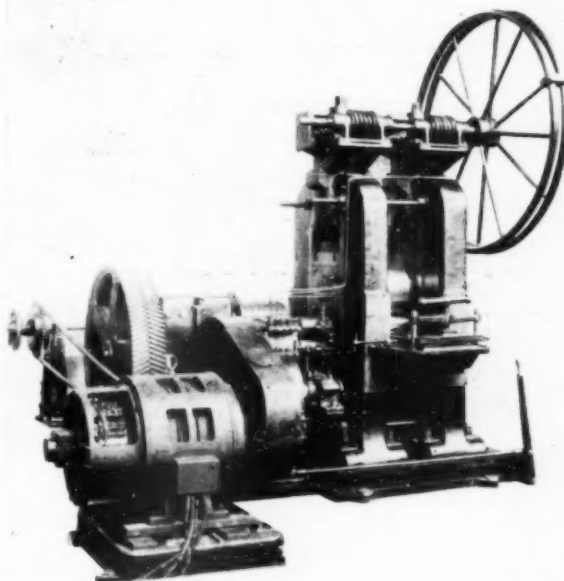


Fig. 10.—Four-high Mill.

units show any appreciable advantage over the high-speed mills with improved bearings already described.

Backed-up roll mills have been installed in this country and abroad with working rolls from 5 in. diameter and less, 10 in. to 12 in. face width, up to 14 in. and 16 in. diameter, 42 in. and 48 in. face width. In the larger sizes the backing rolls are from 24 in. to 32 in. diameter.

The greatest value of these mills is on the following work:—

(1) Comparatively narrow strip in specially *hard alloys* and on the *lightest gauges*. The number of annealings is reduced, and it is possible to effect a total reduction of 80% on brass strip without intermediate annealing. Generally, however, for strip up to 12 in. or 14 in. wide the backed-up roll mill has not any very great advantage of the two-high high-speed mill, excepting as stated on exceptionally hard metals and alloys.

(2) In wide strip and sheets from 12 in. to 40 in. wide, as it is possible to use the most economical working roll diameter and obtain the stiffness of the larger support rolls. As will be understood, whilst the two-high mill with rolls 14 in. × 20 in., described previously, will take economically heavy reductions on strip up to about 14 in. wide, such

a diameter of roll would be too weak and flexible to take the same reduction on strip, say, 24 in. wide, requiring a roll about 32 in. face width. In a four-high design, with 14-in. working rolls, backed up by 24 in. or 28 in. support rolls, the heaviest reductions can be taken on strip up to 36 in. wide.

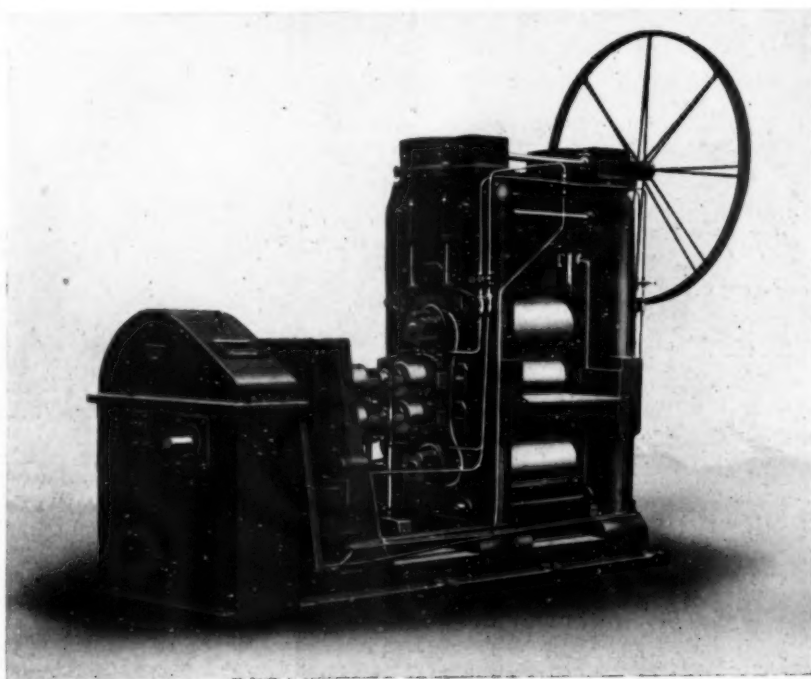


Fig. 9.—Large Four-high Mill.

easily controlled by the operator. The use of mills of the backed-up roll type is now quite common in the States, where very large cluster and four-high mills have been in successful operation rolling metal up to 40 in. wide, for several years. The same designs have been adopted on the Continent, but generally in smaller sizes.

A large four-high mill is illustrated in Fig. 9, which has recently been installed and is working most satisfactorily, cold rolling brass and copper sheets up to 3 ft. wide, from $\frac{1}{2}$ in. thick down to the lightest gauges usually required.

This mill was designed and built by Messrs. W. H. A. Robertson and Co., Ltd., Bedford, and it is believed to be the largest four-high mill as yet built or installed in England. There are also several unique features in the design, particularly in regard to the bearings for the large support rolls, which are the patent "Flood" lubrication types and have proved to give most satisfactory service. These have the advantage over the roller bearing more usually fitted to mills of this type, in being more robust and immune from sudden breakdown, besides permitting the use of roll necks of the maximum size. In this case these necks are 17 in. diameter, and provide for ample strength and rigidity. The rolling speed is over 130 f.p.m., and the power of driving motor is 200 h.p. It has been

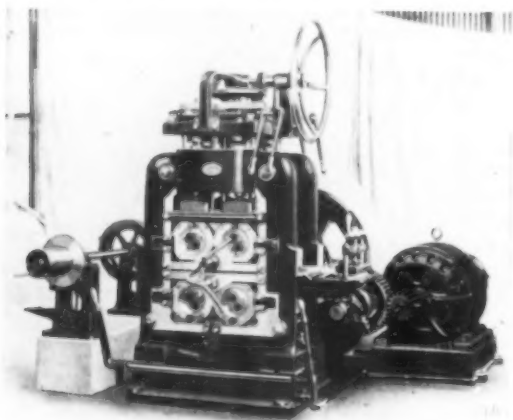


Fig. 11.—Cluster Mill.

found that the output of this mill in finished sheets is four or five times that obtainable from a two-high sheet mill of the ordinary type. The same firm are building similar mills with smaller rolls for strip rolling for widths up to 24 in., and still smaller sizes for strip up to 8 in. wide.

Figs. 10 and 11 illustrate examples of both four-high and cluster design. The former have working rolls 5 in. diameter, 12 in. face, with support rolls, 12 in. diameter, running in S.K.F. roller bearings; and the cluster mill, Fig. 11, has the same size of working roll, but has four support rolls 10 in. diameter, also carried in S.K.F. bearings. Incidentally, it may be pointed out that these mills are being supplied for cold-rolling steel strip, on which they are equally successful.

As previously mentioned, the smaller backed-up roll mills probably offer an appreciable advantage over the two-high type, on narrow width, or narrow widths up to, say, 12 in. wide, only when working on comparatively hard or thin metal; and for ordinary qualities of brass strip, the high-speed two-high mill has probably the greater all-round capacity. Recent reports from America state that it is not considered economical to employ four-high or cluster mills with working rolls less than 7 in. diameter for brass and copper strip rolling.

To sum up the tendency of modern practice in the rolling of non-ferrous metal strip:—

(1) *Breaking Down*.—Where the output is large and on suitable qualities of metal, hot rolling is recommended on heavier ingots and in greater widths. This hot rolling of heavy slabs weighing 300 lb., 600 lb., and even 1,000 lb. weight, can be accomplished by mills of the reversing two-high or three-high types, or when the output required justifies the expense by a train of tandem mills. For small outputs, and on special qualities of brass, cold breaking down will probably still be adopted.

(2) *Getting Down and Intermediate Rolling*.—For this work the four-high or cluster mills will be more generally employed, and of the two the four-high design is probably the most satisfactory in practice. In the States four or five four-high mills arranged in tandem for continuous rolling of strip have been installed and are successfully operated. Metal can be rolled from about $\frac{1}{2}$ in. thick in a width of 24 in. or wider, in continuous coils to standard gauges preparatory to finishing in two-high mills in narrower widths, the wider strip being slit by shearing machines of the multiple rotary-cutter type into widths of 12 in., 8 in., and 6 in., etc., as required.

(3) *Finishing*.—Whilst wide strip, 12 in. and over, may be finished economically to light gauges in mills of the four-high or cluster types, it is believed that narrower widths in gauges from 0.040 down to 0.005 thick can be more economically finished in mills of the two-high high-speed type as described in this article. For this work rolls 14 in., 12 in., and 10 in. wide are most efficient for dealing with strip from 14 in. down to 6 in. wide and less.

Rolling speeds should be about 200 ft. per minute for the wider strip up to 300 ft., or even higher speeds, in strip from 7 in. wide down. The fact that higher speeds can be more easily worked, and generally a better finish obtained, by the two-high mill tends to outweigh the particular merits of the backed-up roll design for finishing strip in moderate widths. It should, however, be noted that in the States four-high mills are being operated at speeds from 350 to 400 f.p.m., but there is still a preference for two-high mills for the final finishing passes.

British Chemical Standard "Bronze" (Brass) "B"

THE fifth of the series of non-ferrous standard analysed samples is now ready for issue.

The analysis is as follows:—

	%
Copper	58.8
Zinc	33.9
Manganese	1.03
Iron	0.94
Aluminium	1.62
Tin	1.76
Lead	0.78
Nickel	1.01
Arsenic	0.03
Antimony	0.05
	99.92

The composition is reasonably typical of that of some of the best grades of manganese bronze at present manufactured, and includes all the elements likely to be found in such an alloy.

Chemists experienced in the analysis of manganese bronze are well aware of the difficulties encountered, and though this standardisation was undertaken by analysts of repute, it was no light task to come to agreement on the composition.

Now that such a valuable standard is available, no doubt all chemists making analysis of manganese bronze and other brasses will be glad to make use of the sample for confirming their analyses, investigating methods, and settling disputes. An important feature of the certificate of analyses, which is issued with each bottle of standard, is the outline of the methods used by the different chemists.

The standard is available to anyone at a price based on ultimately covering the cost of preparing and issuing it. The three usual sizes—50, 100, and 500 gm. bottles—are provided, together with certificate just referred to.

Further particulars may be obtained from Headquarters, 3, Wilson Street, Middlesbrough.

Owing to the demand for back numbers of *Metallurgia*, we are unable to supply copies for January, April, and June, and would be glad to hear from any of our readers, who are desirous of disposing of their copies of these issues.

Principles and Uses of Wire Rope

Part VIII.

By WALTER A. SCOBLE, D.Sc., M.I.MECH.E.

Head of Engineering Department, Woolwich Polytechnic.

The Lubrication of Wire Ropes and Causes of Corrosion.

MOST modern specifications demand that a wire rope shall be lubricated during the laying-up, the British Engineering Standards Specification for Crane Ropes requiring that: "The wires, the cores of the strands, and the main core of the rope, while being laid up, shall be thoroughly coated and impregnated, respectively, with a suitable lubricating compound. The lubricant used shall be free from acid or marked alkalinity, and shall have no injurious effect on the wires or the material of the cores, shall not gum, and be of the proper consistency to be retained in the interstices of the strand or rope."

Since the ropes consist of wires of small diameter, it is clear that these, like other steel products, must be prevented from rusting during transport and whilst they are stored. This requirement alone may be met by a coating which is not necessarily a lubricant, and which need not be applied to a galvanised rope.

The United States Government Master Specification for Wire Rope, No. 297, requires that each fibre core of wire rope shall be thoroughly impregnated with a suitable lubricant during the process of manufacture of the rope, but this hardly seems to ensure sufficient protection for the wires before the rope is put into service. The American specifications include an appreciable amount of information and advice relating to the use and maintenance of the articles dealt with, and this portion of the circular quoted above deals more fully with the subject of lubrication. The views expressed are given in full.

Wear of a running rope occurs where the outside wires come into contact with the sheaves and drums, especially if slipping takes place, and also where the wires are in contact. During the fabrication of a wire rope the fibre core is saturated with lubricating compound, which, in service, is gradually supplied to the wires and reduces the wear on them. As the core will not carry enough lubricant for the life of the rope, it is necessary to occasionally apply a lubricant to the outside of the rope which will be absorbed by the core. A mixture of a heavy-bodied lubricant and a good grade of graphite is as satisfactory as any of the proprietary lubricants and is cheaper. A viscous preparation which remains on the outside of the rope does not lubricate the inner wires of the rope.

Effect of Opaque Substances.

For elevator cables any lubricant containing an opaque substance is undesirable, as it interferes with the proper inspection of the rope by making it difficult to detect broken wires. Graphite and similar lubricants may cause excessive sliding of cables on traction-drive elevators, and should not be used on this type of equipment. Boiled linseed oil, applied hot, will saturate the hemp centre, and will, when dry, give a transparent covering which will not interfere with the thorough inspection of the rope. If an uncoated wire rope is to be used where it is likely to corrode, the lubricant should have a very heavy body, and be applied to the rope so hot that it will penetrate to the core.

The lubrication of mining ropes is dealt with in Technical Paper 237 of the U.S. Bureau of Mines, which agrees in some measure with the above, but fresh views are expressed as follows:—

A hoisting rope should be considered as a piece of machinery, having many wearing surfaces that must be

thoroughly lubricated. The lubricant should consist of oils and greases that will penetrate between the wires and the strands, and should not harden on the outside. A lubricant that hardens is cracked while bending over the sheaves and drums so that moisture can penetrate to the centre and cause internal corrosion.

Tar should never be used; it forms a hard shield on the outside of the rope, and does not penetrate and lubricate the inner parts. If possible the rope should be lubricated when dry, so as to give the lubricant a better opportunity to penetrate the core and to adhere to the wires.

The lubricant must be applied often enough to keep the wires well covered, and to keep the hemp core from drying out. All the accumulated dirt and gummed lubricant should be cleaned from the valleys between the strands of the rope so that the fresh lubricant can penetrate.

Those who are particularly interested in the lubrication of wire ropes will be well advised to obtain a copy of "Wire Ropes, Their Care and Treatment," No. 7 of the Gargoyle Technical Series, which is published by the Vacuum Oil Co. This pamphlet directs attention to the necessity for lubrication and the elimination of dirt and grit to reduce friction and wear between wires, adjacent strands, and between the rope and the pulley over which it works. It is stated that wire ropes usually will deteriorate more rapidly from rust and corrosion than from wear. Rust and corrosion are caused by water, by moisture in the atmosphere, and by acids and salts present in the surroundings in which ropes are used. The corrosion of the inside of a rope is most to be feared.

Causes of Corrosion.

Corrosion may be due to the internal effect of incorrect preservative materials, or of excessive moisture in the fibre core. If a fibre core contains an excess of moisture, after soaking in a lubricant, bacteria operate and reduce the fibres to a rotten condition. If, on the other hand, the moisture content has been reduced by excessive drying to less than the requisite percentage, the strength of the fibres may be seriously impaired and they may be dangerously brittle.

It is recommended that the fibre core be impregnated with lubricant by passing it through a bath containing a heated mixture of oil and petroleum jelly, as a protection against the subsequent absorption of moisture, and as a reservoir for the lubrication of the internal wires and strands of the rope. Under load the strands compress the fibre core and the lubricant contained in the latter is extruded. Saturation of the core should be complete, so that the centre of the core is not left in the condition that permits decomposition. Cores are sometimes dried in a vacuum chamber to facilitate the removal of moisture, after which the lubricant is admitted to the chamber.

The Vacuum Oil Co. recommends highly viscous mineral oils, used either alone or mixed with petroleum jelly, as the best for core dressing. Both should be pure petroleum products that are neutral in reaction.

There is one suggestion in this pamphlet which is most interesting and original. The possibility of the development of bacteria or fungi in the fibre core after manufacture indicates the desirability of incorporating with the dressing some fungicide or antiseptic, such as substance containing thymol, that is entirely free from acid, and the action of which will be otherwise non-deleterious.

Wire ropes should be lubricated whilst in service with sufficient frequency to keep them covered. They should be clean and dry when fresh lubricant is applied to allow it to penetrate and adhere. The lubricant may be applied by means of a stiff brush, but there are many mechanical oilers in which the rope passes through waste or the like saturated with oil, or the rope drives a pulley which dips in oil and carries it over to the rope.

The essentials in a correct lubricant are given as:—
(a) Absolute freedom from acid or alkali; (b) ability to penetrate readily between the outer strands; (c) great adhesiveness, so that it will not be thrown off by centrifugal force or vibration; (d) sufficiently viscous to resist gravitation to the bottom of a rope used vertically; (e) must not harden, crack, or peel within a wide range of temperature and atmospheric conditions; (f) be impervious to water.

Various Views on Lubrication.

The first report of the Wire Ropes Research Committee of the Institution of Mechanical Engineers (Proceedings, October, 1920) refers to lubrication, and shows considerable diversity of opinion between different writers. Howe recommended the use of linseed oil, whereas Rowland states that this oil dries and peels off, or else hardens and prevents the next dressing applied from reaching the inside of the rope. It also hardens the core and hastens its destruction. Rowland appears to have been the first to record that a hemp core which becomes dry will crumble away, with disastrous results.

The Transvaal Commission condemned Stockholm tar, tallow, and resin as unsuitable for the lubrication of ropes, because they are acid, and all vegetable and animal products are regarded with suspicion on similar grounds.

The various views held with regard to wire-rope lubrication have now been given, but a review will be attempted to clarify the position.

The principal difference between the American and British specifications and statements is that the former consider the dressing as a lubricant for the wires and strands, with but little reference to corrosion, whereas British authorities lay at least equal stress on the protection of the rope. The catalogue issued by Wrights, of Birmingham, refers to "the preservative treatment of wire ropes," and states that the subject is important for two special reasons: firstly, because it is only by thorough and systematic dressing with a suitable lubricant that the insidious arch-enemy of wire-rope users, and the most fruitful cause of pit-shaft accidents, internal corrosion, can be effectually warded off; and, secondly, the use of a good lubricant minimises the friction between the wires and enormously increases the life of ropes. The prevention of corrosion is regarded here as being of the greatest importance. Corrosion may be caused by an unsuitable dressing, so the British specifications insist that the lubricant shall be neither acid nor alkaline. The Vacuum Oil Co.'s pamphlet embodies the modern British views which favour the use of petroleum jelly and heavy mineral oils.

Wright refers to Biggart's early experiments on the repeated bending of wire ropes over pulleys, from which he concluded that a lubricated rope had a much longer life than a similar rope which ran dry under otherwise identical conditions. More recent tests by the writer gave results which are directly opposed to Biggart's, and showed that a dry rope withstood more bends than a piece of the same rope after lubrication. The writer has concluded that the lubricant acts as a carrier for the material worn from the wire and the pulleys, and promotes wear by grinding, a view which is supported by practical experience of ropes working in a gritty atmosphere, which are found to give longer service if used dry than when they are lubricated.

It appears, therefore, that the term "lubricant" is unfortunate in this connection, and that "preservative" is to be preferred. The dressing should be regarded and selected primarily as a preservative for the wire and core. The fact that the dressing holds grit should not be forgotten, because it emphasises the desirability of cleaning a rope

before it is re-treated, whereas if the view finds general acceptance it may lead to an alteration of present practice on the lines of preserving the rope and at the same time minimising its wear by grinding.

B.E.S.A. SPECIFICATIONS.

The following specifications have just been issued by the British Engineering Standards Association:—

British Standard Specification No. 394, Short Link Wrought-iron Crane Chain.—This specification is the first of a series of specifications which is in the course of preparation as the result of representations made by the Home Office for the standardisation of chains and chain fittings.

Two qualities of chain have been specified, a "Standard quality," which it is felt is adequate for all normal lifting purposes, and a "Special quality," which has been included for those cases where special hazards and risks are involved.

The specification provides for clauses governing the quality of material used in the chain, as well as standardising dimensions and test loads. The tests determining the quality of the material are carried out on a sample cut from the chain itself, and the finished chain is thus tested both as regards quality of material and tensile strength. Another feature in which the specification differs from others previously drafted is that the elongation on a 36 in. sample is measured at a point before fracture at a load which is given as the test load, which must accordingly not be confused with the breaking load. The requirements for testing machines for carrying out the tests on the chain have been included in an appendix to this specification.

The Committee responsible for the preparation of this specification were assisted in their work by both the Chain and Anchor Manufacturers' Association and the National Physical Laboratory, who collaborated in the tests that were carried out with a view to establishing the suitability of the tests laid down.

A Revised Edition of Part IV. of Report No. 24 has just been completed.—This specification provides for steel forgings, blooms, and castings. The Forging and Casting Specifications include four qualities of material, and in the revision certain modifications have been made to the requirements of these classes.

The specification for forgings has also been amplified to cover rolled bars of Class D and Class D quality of material, and this will be a welcome addition to the specification. In the review the specification has been brought up to date in many respects with modern practice. The wide adoption of the material provided for in these specifications for purposes other than locomotive work, will make the revised issue of interest to all engineers.

British Standard Specification No. 384, Attachment of Circular Metal Cutting Sawes (for cold work).—The need for some standard method of attachment of circular saws has long been recognised. The specification which has just been issued provides for the attachment of saws or drives in diameter from 10 in. up to 60 in. and over in six ranges. The loose-flange method of attachment has been recommended, and in addition to giving the standard dimensions for the fixing of the saws, the specification also includes a recommended method by means of which two ranges of saw diameters can be accommodated on one size of machine. In preparing this specification, the dimensions of machines at present in use were carefully considered.

Two specifications have recently been issued covering the light aluminium alloy generally known as Duralumin. They are, respectively, No. 395, *Wrought Light Aluminium Alloy Sheets and Strips*, and No. 396, *Wrought Light Aluminium Alloy Tubes*. Both specifications contain clauses for the chemical composition of the alloy, and the physical properties of the finished material, whilst tolerances on the dimensions of the sheets, strips, and tubes are also given.

Copies of the foregoing specifications may be obtained from the Publications Department, British Engineering Standards Association, 28, Victoria Street, London, S.W. 1. Price 2s. 2d. each, post free.

Accurate Case-Hardening

By H. Swain.

A close study of the Process of Case-Hardening will lead to more accurate results.

More care may involve greater cost, but there are economic compensations.

BY studying all the elements of the process accurate results may be guaranteed over long periods.

The operation of case-hardening, in accordance with many other crafts, was carried out, and in some cases still is, by rule-of-thumb methods only. Considering that in all probability it is the oldest method of heat-treatment known, it is surprising that only during comparatively recent years has any great progress been made in the method. When one visits a number of case-hardening plants one realises how, in many cases, the carburising is still run on the crudest rule-of-thumb methods, how it is shrouded in mystery by an illiterate carburising operator, and how it appears to be the last operation of the heat-treatment process to which scientific methods and control are being applied. Many manufacturers are satisfied that their results are good, but by little extra care and cost one may safely say that saving along many lines is possible.

Efficient Furnaces.

To start at the beginning of the process. Modern furnaces are more essential to the carburising operation than to other heat-treatment, owing to the necessity for duplication of results, and to the greater length of time per charge compared to reheating. How often is this the case in practice? The fuel should be conserved, and as much heat from it as possible usefully applied. In some concerns the total replacement of the old furnaces by more efficient ones will show a saving over as small a period as six to twelve months, due to the reduction of the fuel bill. The selection of the type of furnace should be carefully studied, though in an article of this length it is impossible to go into the relative merits of the different types—electric, gas, coal, or oil. Suffice it to say that each has its sphere of greatest usefulness, and a consideration of the various circumstances for which, and under which, it is to be used must decide the choice. The furnace should be fitted with a pyrometer, automatic recording of the temperature being an added refinement. With electric furnaces automatic control is usually fitted, and is a great advantage in carburising.

Carburising Compound.

The selection of the carburising compound is the next item, and with such a variety on the market this would appear somewhat difficult. The simplest is usually the best. It is here that one must guard against the extravagant claims made by some representatives. The case is in its best condition when the amount of carbon on the surface of the finished product is in the region of 0.9%. This is the eutectoid ratio, which on quenching gives the greatest hardness to the steel, with freedom from cementite, the constituent which often causes chipping. As this is so, the percentage of carbon on the surface immediately after carburising requires to be in the region of 1.0 to 1.2%, as anything up to 0.008 in. to 0.010 in. per side may be ground off. With one compound the author tried he found that after carburising at 900° C. to give a depth of 0.8 m.m., the surface contained 0.92% of carbon, but at 0.10 in. deep this had fallen to 0.80%, which would not give as hard a surface. This trouble was overcome by carburising at 920° to 930° C. when at 0.010 in. deep, the case contained about 0.9% of carbon.

The compound should be fairly light and porous, for, though it is bought by weight, the boxes are packed by volume, and it is possible to pack many more boxes from one type of compound than another. The material should

be of small even grain, with very little loose dust or energiser. If the latter is the case, the composition of the material at the top of the bag will vary from that at the bottom. The shrinkage of the compound after carburising should be noticed particularly, for if this is great the top layer of work is likely to be left uncovered, resulting in soft spots. Also, there is not so much compound to use a second time. When one has decided which type of compound to use after a series of small tests, it is a sound policy to use that altogether, so that one knows just what to expect from it. A change should only be made if exceptional circumstances demand it, and then only after careful consideration.

Boxes and Methods of Packing.

With regard to the boxes themselves, cast nickel chromium alloys will be found to be cheaper over a long period than the usual mild steel ones, though there is a great disparity in the initial costs. A good scheme for obtaining these is to make 50% of the order for nickel chromium and 50% mild steel boxes when replenishing stock, so that eventually the complete stock will be of alloy boxes. It should be mentioned here that small boxes are better than very large ones, but if it is essential to have large boxes, due to the size of the components, then it is better to keep them fairly shallow and not cubical in shape, in order to aid the heat transference.

The packing of boxes with components for carburising should be carried out carefully and systematically, in order to get the work evenly spaced and completely surrounded with compound. Most compounds allow of a mixing of two-thirds used with one-third new. Instead of completely mixing in this proportion it is often advisable to pack the outside of the boxes with the used compound, and to place the new more in the centre of the box, in an endeavour to counterbalance somewhat the difference in temperature between the sides and middle during the initial stages of carburising. When the boxes are packed they must be effectively luted with clay or some other medium. This is one of the points where very slipshod methods are often used. The clay should function only as a gas-tight jointing, and not as a means of holding the lid to the box, which it will fail to do at heat. Correctly shaped lids which fit the box should be the order, and it is in this respect that alloy boxes hold a distinct advantage over other types, due to the bulging and distortion of the latter after only a few hundred hours at carburising temperature. There are some boxes which have a lid inside on to which the top lid may be rammed. The clay is then just pressed into the joints. If production will not allow of such careful luting—though with boxes such as described above the time taken is probably less than with badly fitting lids—there are some boxes which may be obtained where the lid overlaps the sides, so that it is only necessary to invert the box when full, no luting being required. It is not uncommon to see boxes with lids about one-quarter of the correct size, being held in position by several inches of clay. If for no other reason than that it is impossible to exclude all of this clay from the compound, which contaminates it and results in soft spots on further use, the procedure is sufficiently condemned. There is another reason for good luting, however, and that is to maintain a pressure. This pressure results in more even carburising of components placed in various portions of the box, and this, together with the use of new and old compound, as already described, and a

careful control of the rate of heating from cold will result in the depth of case on the articles placed in the centre of the box being only slightly less, if at all, than that of those placed near the sides.

In many cases, particularly where carburising is continuous, the boxes must be charged into the furnace when the latter is running very near the carburising temperature. Where it is possible, however, more uniform results are obtained if the charging is carried out when the furnace is running at about 800° C. or lower, and then gradually heated up. In this way the poor conductivity of the compound is somewhat balanced, as the inside of the box comes into the carburising zone of temperature quicker, and with not such a great lag in time behind the outside as when the charging is carried out at the carburising temperature.

It must be understood that steel does not absorb carbon until it (the steel) is austenitic, which, with mild steel, is in the region of 860° C. In this respect it may be worth while to mention that some compounds give off a large amount of carbon at comparatively low temperatures, and less at high. A good compound should give off its maximum carbon bearing gas at temperatures coinciding with the austenitic phase of the steel.

Various carburising temperatures are used, some concerns working as high as 1,000° C., but if a temperature of 920° C. is exceeded to any great extent the best possible results from the case and core cannot be obtained. With nickel-chromium steels 900° C. should be the maximum, and in many cases a temperature of 870° to 890° C. is best for this type of steel. With all case-hardening it is worth remembering that for a deeper case it is better to give longer time than higher temperature.

Re-Heating and Tempering.

The method of procedure for reheating is fairly well known, and there is no use labouring this section. The best results are always obtained by two reheatings and quenching; the first to refine the core, the second to harden and refine the case. With the higher nickel steels, however (i.e., those containing above 3.0% nickel) excellent results can be obtained when the first refining treatment is omitted. Besides cheapening the process, this has an advantage inasmuch as it eliminates a great amount of distortion brought about by the first quenching, being from a much higher temperature. With alloy steels, too, oil quenching may be used for both the reheating operations, with its attendant beneficial results.

Case-hardened work which is stressed to any great extent, and sometimes that which is not, is usually tempered at about 180° to 200° C. The original object of case-hardening is to obtain a very hard surface, combined with a tough core, and anything which interferes with one or other of these must be regarded with suspicion. Work tempered at 200° C. will still resist the file, and by many it is thought that no softening takes place. With the advent of nitrogen hardening steels, however, where claims are made for a Brinell hardness figure of 1,000 to 1,100, and with the excellent wear-resisting properties of these steels, it has become apparent that the maximum hardness obtainable with case-hardened steel is often very desirable. This is not obtained when the steel is tempered, as the following table shows:—

Steel.	Not Tempered.	Diamond Hardness Number.		
		Tempered at		
		100° C.	150° C.	200° C.
A	970	970	890	825
B	970	940	890	800
C	768	768	735	687
D	825	825	768	735

The author does not suggest that no case-hardened steel should be tempered, far from it, but he thinks that very careful thought should be given to the actual duty which a component has to perform before deciding upon which course to take. Especially is this so with oil-quenched steel, as low temperature tempering has less beneficial results. This can be illustrated in the following manner:—

Certain components manufactured from steel "A" in the above table, when quenched in water after the second reheat, and tempered at 180° C., gave a hardness figure of 800 to 815. Due to the severity of the quenching, most of these warped badly and were very difficult to straighten, the setting operation probably creating more severe strains than were present from the quenching. By resorting to oil quenching and not tempering at all, very little warping took place, and what did could be set easily. The hardness number, too, was between 930 and 970. In this particular instance a much better product was produced, as it was necessary to retain the greatest hardness obtainable. If the steel had been tempered after oil quenching there would have been a fall in the hardness, with no corresponding increase in other qualities to counterbalance.

It is by close investigation into all the various seemingly small and unimportant points of case-hardening, some of which are discussed above, that makes possible great improvements in the process and the products from it.

PROGRESS OF THE BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION.

THE British Non-Ferrous Metals Research Association, which was founded ten years ago, has made steady progress under the direction of Dr. R. S. Hutton, and has secured a leasehold factory property, Requat Buildings, Euston Street, London, N.W. 1, where it is proposed to centralise its offices and provide accommodation for laboratory and workshops for its research and technical development departments. This Association carries out investigations for all sections of the non-ferrous metal industry on an extensive scale, having an annual expenditure of between £20,000 and £25,000.

The value to industry of this Association has frequently been demonstrated, particularly in the discovery of new engineering materials, and in solving problems associated with the increase in efficiency of production and of overcoming the causes of defects, all matters of great economic importance. In view of the increased expenditure involved in modifying and adequately equipping the new premises, a special appeal for contributions to a Headquarters Fund has been launched, and has met with considerable success despite the present difficult industrial conditions. The appeal is also directed towards an increased annual support, by increased membership, the economic advantages resulting from investigation of the nature undertaken certainly warrant additional support from the metal and engineering trades.

The Association has recently enlarged its staff by appointing Mr. D. H. Tugall, D.Sc., as Assistant Director and Research Manager, and Mr. G. L. Bailey, M.Sc., of the Metallurgy Section, Research Department, Woolwich, has been appointed as Development Officer. Dr. Tugall, whose appointment will take effect from January next, is well known for his metallurgical research and administrative work, and as first Principal of the Constantine Technical College at Middlesbrough has been largely responsible for its equipment and organisation. Mr. Bailey, whose appointment commenced on September 1, fills the position recently vacated by Mr. S. J. Nightingale, who resigned to occupy an important position in industry.

Recent Developments in Tools and Equipment

A Roll and Cylinder Grinding Machine.

THE increasing demand for accuracy and high degree of finish is largely responsible for the rapid progress made in the use of grinding machines. Developments in the use of steels and other alloys of a hard-wearing character have also influenced the development of machines to give that degree of finish and accuracy modern engineering demands. In addition to these important requirements, the question of economy in production, the

to take journals up to 36 in. diameter. The cross-beds for the journal stay supports are adjustable longitudinally along the bed, and the main cross-bed supporting the driving head is arranged to swivel to enable conical rolls to be ground. The journal supports are also arranged to swivel. An accurately cut steel rack is arranged with the bed for the saddle traverse.

One of the most important parts of a machine of this type is the saddle. This is of heavy design accurately machined and surfaced to fit the slides on the bed. It is arranged with worm gear, with rack and pinion traverse totally enclosed, and driven through the necessary reversing gearing and change-speed gearbox. The drive to this gearbox is direct, from a motor mounted on the saddle, the gears and clutches are of hardened steel, with high-speed shafts mounted on ball bearings, and all gearing is enclosed and runs in oil. The saddle is provided with suitable trip levers to engage the trip dogs on the bed for the automatic reverse traverse, with a convenient hand lever for operation by hand.

The grinding head consists of a transverse slide with fine adjustment for the emery-wheel feed, the slide having trunnions on which a massive grinding spindle is fitted. The spindle is mounted on the grinding spindle head in adjustable self-oiling bronze bearings of most modern design. The spindle is driven by means of a texrope drive,

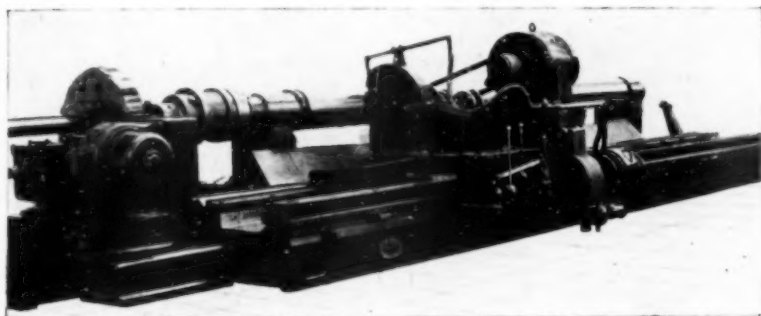


Fig. 1.

importance of which cannot be overestimated, has directed attention to the use of grinding machines, and in roll grinding these factors are of great importance. For this purpose machines are involved that possess rigidity coupled with delicacy of action, in order that they can function on a precision basis, and, by the removal of the minimum of metal, particularly in the case of retooling rolls, considerably increase the life of the roll.

Rigidity in construction, soundness of design, and quality of workmanship, are well illustrated in the roll and cylinder grinding machine of Messrs. Craven Bros., Ltd. This machine is equipped with cambering mechanism, and is eminently suitable for grinding new rolls or regrinding used rolls up to 40 tons in weight, to re-surface them, and give them a fine polish. It is arranged with worm, a reduction gear, and gearbox drive to the roll rotating head and saddle-traverse gearing, and a motor is arranged on the saddle.

A general view of this machine is shown in Fig. 1, while an end elevation is illustrated in Fig. 2. In design the bed is of strong box section, with accurately surfaced slides, the front slide being of the vee-type, the rear slide being of flat section, and both are arranged to drain away the surface oil. The bed is troughed to prevent accumulation of swarf, the front portion being provided with tee-slots for the knee brackets which carry the stays, and is also provided with rack for adjusting the brackets longitudinally by ratchet levers with rack and pinion gear, the brackets being fitted with support bearings for carrying the journals of the rolls. The support bearings are adjustable in tee-slots, with knee brackets for different diameters of work. Stays or support bearings are arranged as required

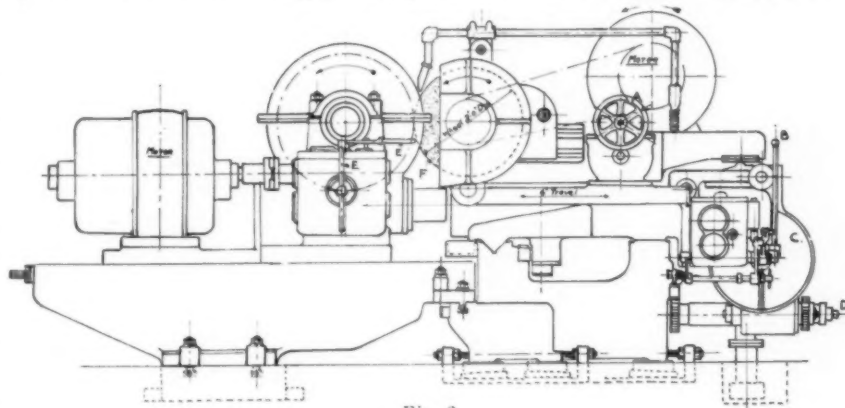


Fig. 2.

A. Hand-motion Spindle Slide.
B. Change-gears Saddle Traverse.

C. Cambering Gear.
D. For Disengaging Cambering Gear.

E. Change-gears for Roll Revolving.
F. Grinding Wheel.

with two interchangeable pulleys, from a motor mounted on a base at the rear of the grinding head. A guard provided for the emery-wheel carries a water-catcher to prevent the splashing of the water over the machine.

The cambering is done by means of a cam driven from rack and pinion, as shown in Fig. 2, the rack being arranged on the back of the bed, and the pinion driving through a worm running in oil on to an accurately cut worm-wheel. The worm-wheel drives the cam which actuates the emery-wheel slide through a roller and a compound lever. In the compound lever an adjustable hardened die is placed, the adjustment of this die regulates the amount of camber. The worm-shaft, camshaft, fulcrum for levers, and cam roller are of large diameter, and fitted with ball races to

eliminate all friction. The cam is accurately shaped to give a true curve, obviating all flats or points, and the amount of camber can be regulated whilst the machine is working, the change from camber to parallel and *vice versa* being made instantly. Change gears are provided to obtain full cam movement for varying lengths of roll.

The roll-revolving gear is motor driven through change-speed gears arranged in the headstock, the motor being direct-coupled through a flexible coupling to the gearbox shaft, and the final drive to the spindle is by means of worm and wheel; all gearing running in oil, with high-speed shafts mounted on ball bearings, the worm-wheels being bronze, and the worm adequately provided with ball-thrust washers. The cross-bed carrying the roll-revolving gear can be moved along the bed to suit different lengths of roll.

An emery-wheel truing attachment is attached to the bed, it being fixed by bolts in the tee-slots at the front of the bed. The machine will take a grinding wheel of 24 in. diameter, and for a roughing wheel 365 grit, O grade, E 2 bond is recommended, while 60 grit, 2 grade, C 2 B bond is suitable for the finishing wheel. The diameters of work within the capacity of the machine are 8 in. to 60 in., while the maximum length of roll face admitted is up to 21 ft., the maximum length of roll over-all being 28 ft.

THE "TERNI" OPEN-HEARTH FURNACE.

THE recent invention relating to the system of open-hearth furnace construction and operation successfully developed at Terni, is of considerable importance to steelmakers. The invention, which embodies modification to the standard type of open-hearth ports, has greatly increased the efficiency of combustion, and by so doing has materially reduced the time of melting. Economically, remarkably good results have been obtained and the fuel consumption per ton of steel produced has been considerably reduced. The design of the port end is such that the direction of the flame can be varied at will, to suit scrap melting conditions, a feature previously unattainable without excessive loss as a result of oxidation.

The principal features of this invention comprise a special design of combustion chamber, the provision of means for varying the velocity of the flame, together with facilities for controlling the type of flame and its quality other than by means of the chimney stack and valve control. The regeneration temperatures of the air and gas are increased to 1,350° C, and, in addition, the effect on the furnace lining, by adopting the system, results in the reduction of repair costs and enables the furnace to be run successfully for a more prolonged period than was formerly considered possible. Further, no water cooling is necessary, and the invention facilitates the making of any grade of steel, hard or soft, of excellent quality.

The first furnace was put to work in 1926 at the "Terni" Works, the hearth area being 28 ft. 10 in. × 11 ft. 3 in. Seven furnaces of this type have now been converted.

In the accompanying table a comparison of results is shown which were obtained from the operation of identical furnaces of 20 tons and 40 tons capacity, respectively, before and after conversion. These clearly indicate the merit of the modifications involved in this system.

The most recent furnace put to work at these works has a capacity, nominally, of 34.5 tons, dimensions of bath at sill level being 28 ft. 10 in. × 11 ft. 3 in. The first campaign for this furnace gave the following record output, working chiefly on ordinary carbon steel:—

1,029 heats, representing 46,163 tons.

Coal consumption, 436 lb. of coal per ton of steel, excluding coal for reheating. Furnace cold charged.

During the early part of the campaign it was found to be more economical to employ charges of 49 to 50 tons, and this was adhered to throughout. It is important to

note that, during this campaign, the walls needed re-pairing only twice, the ports partially and one repair to the roof, the consumption of refractories involving:—

643 tons of silica bricks.
49 tons of magnesite bricks.
5.9 tons of chrome bricks.
117 tons of cement.

which gave a consumption per ton of steel produced of 33 lb. excluding cement and 39 lb. including cement.

TABLE SHOWING COMPARISON OF OPERATION RESULTS.

	Average Campaign Tonnage.	Charges.
20 ton furnace (old type)	8,500	450
20 " (converted)	24,000	1,000
40 " (old type)	16,000	450
40 " (converted)	45,000	1,000

The system involved may be either embodied in existing furnaces or in new furnaces, irrespective of their capacity, and, as was mentioned in the June issue of METALLURGIA, the Wellman Smith Owen Engineering Corporation have been granted the sole rights of constructing "Terni" furnaces in the British Isles and also of converting to the "Terni" design existing open-hearth furnaces. Already licences to employ this system have been granted to a number of steel-making manufacturers in this country and modifications have been made to many existing plants which have resulted in complete success.

Power for Moulding Machines

(Continued from page 172.)

have to face such severe conditions as some enthusiasts would have us believe. A definite case of freezing with air plant was brought to the notice of the author, during a recent severe winter. The water in the water-jacket around the air compressor froze up and caused an enormous amount of trouble. In the same foundry a number of hydraulic moulding machines on the same day were perfectly free from frost, due to the fact that in most cases working parts were underground and the frost could not get at them, and where joints, etc., were overground, they had been protected. Here was a definite case where frost caused stoppage with the air machines, but no stoppage with the hydraulic machines. Therefore, we must not always accept that, because moulding machines are actuated by water they give trouble from frost, and that compressed air machines are free from any freezing troubles.

Another definite factor must not be forgotten—namely, that if the weather was so severe as to freeze up the moulding machines and the water under high pressure in the pipe-lines, all the general mains containing drinking and washing water would be frozen. How often in this country do we experience such conditions? It is just as easy to protect the pipe-lines to and from moulding machines as it is the general washing and drinking mains. Again, to-day, modern standard hydraulic machines can so easily be emptied of the water that a little care will avoid all risk—a risk which the author believes has been grossly exaggerated in the past.

(e) There can be no argument that the smoothest and easiest way to draw a pattern is by the use of a fluid medium. Compressed air is very jerky in its movements, and hydraulic power alone allows the sweet, steady pattern-drawing motion which is so essential, especially where difficult and intricate parts of sand have to be drawn without danger of breakage.

To sum up, it will be seen that both compressed air and hydraulic power have their advantages and disadvantages, and founders should study these, for while there is room for both agencies in every foundry, it is wise to study the question of efficiency coupled with economical results.

Some Recent Inventions.

ELECTRIC FURNACE FOR BRIGHT ANNEALING METAL SHEETS

A FURNACE installation, particularly adapted for annealing metal sheets, is designed with an elevated heating and cooling tunnel having bottom charging and discharging apertures, and elevators are used for introducing and removing work carriers into and from the tunnel. The design comprises a two-deck electric furnace in which a

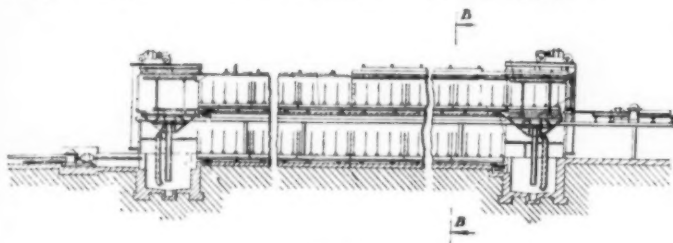


Fig. 1.

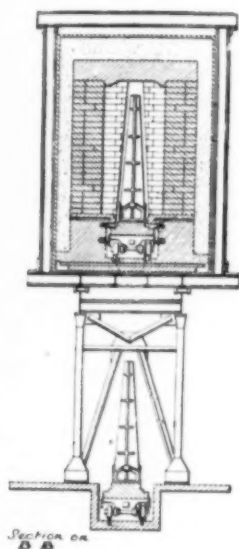


Fig. 2.

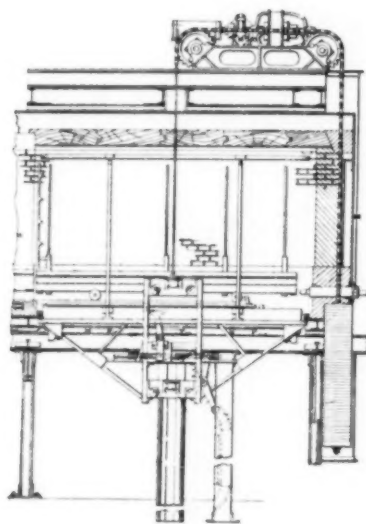


Fig. 4.

treatment tunnel is superimposed on a handling deck, and elevators operating between the two decks are arranged at the charging and discharging ends, means being provided for shifting a train of work carriers in the tunnel towards the discharging end when both elevators are raised, and for shifting another train of work carriers from the discharging towards the charging end when both elevators are lowered. The elevators are preferably arranged to seal the charging and discharging apertures, both in their raised and lowered positions, and both the tunnel and handling decks and the work-carrying platforms of the elevators are provided with rail-tracks to enable the use of wheeled trucks or cars as work carriers.

A central longitudinal sectional illustration of this double-deck annealing furnace, which is adapted for the performance of continuous bright annealing of metal sheets in an atmosphere of gas or gases lighter than air, is shown in Fig. 1.

The furnace is divided by vertical partitions into a preheating zone, heating zone, and a cooling zone. A water jacket is provided around the cooling zone, and to maintain a non-oxidising atmosphere within the furnace, a mixture of oxygen and nitrogen is introduced at the junction of the heating and cooling zones. Attached to the side walls of the heating and preheating zones and extending over substantially the whole height are electric resistance elements, Fig. 2, arranged in independently-

controlled tiers. The lower part of the tunnel is insulated from the working chamber by the engagement of asbestos strips, Fig. 3, carried by the side walls, with the upper portion and the sides respectively of the trucks: the latter are each provided with an end-plate conforming closely to the openings in the partitions and with racks to support the sheets in a vertical position during their passage through the furnace. The charging and discharging openings in the chambers are sealed when the elevators are raised by the engagement of a depending flange shown

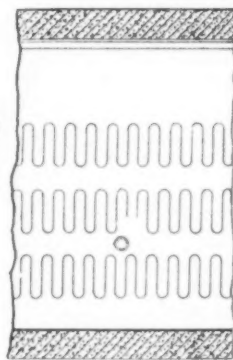


Fig. 3.

in the sectional elevation of the charging chamber Fig. 4, in a sand-trough on the elevator platform, and also when they are lowered, by closure members which are mounted on supports and formed with a flange to co-operate with another sand-trough. The elevators are carried by chains passing over sprockets and attached to counterweights, the sprockets being driven from electric motors in connection with which are provided magnetic brakes to lock the elevators in any desired position. Guide frames mounted on each side of the elevators, are equipped with rollers which bear against vertical guiding plates. Each elevator platform carries movable rails which are automatically shifted, as the elevators are raised and lowered, away from the surface and handling deck tracks to prevent fouling of the sealing means. Each rail carries a rack engaged by a pinion secured to an arm which is rocked about its pivot by the engagement of a roller in a cam-slot, the movement of the roller being transmitted through links and a slidable rod fitted with buffer springs. A weighted lever device, shown in Fig. 1, is provided in connection with each of the tracks to engage the trucks and prevent their movement backwards into the charging chamber, and into the space below the elevator, respectively. At the opposite ends of the tracks catches are arranged which prevent forward movement of the trucks, except when they are depressed by solenoids which are energised simultaneously with the movement of rams.

326,517. G. B. SHIPLEY and H. ALINDER, both of Century Buildings, Pittsburg, U.S.A., Patentees. Arthur Padler, Agent, 44, Waterloo Place, Birmingham, March 19, 1930.

TREATING SILICON STEEL SHEETS.

SILICON-STEEL sheets for electrical purposes are subjected to treatment by a process which involves pickling, cleaning away the acid, annealing, cold rolling, and re-annealing. The sheets are flattened, if necessary, and passed into a pickling bath, which may consist of sulphuric acid with a controlling agent such as that known by the trade name "Incontrol," which is stated to contain certain gelatinous materials, blood, and preservatives. The sheets are then washed, the acid neutralised with lime water, and the sheets scrubbed. A suspension of air-slaked lime in water is then sprayed on the sheets, and when dry forms a coating to prevent them from adhering to one another. The sheets are then annealed, cold rolled, and re-annealed.

331,511. A. F. MURPHY and W. JONES, both of Zaneville, Ohio, U.S.A., Patentees.

ANNEALING IMPROVEMENTS FOR MALLEABLE IRON CASTINGS.

THE value of annealing or heat-treating metal products is becoming increasingly recognised, while in some types of castings, such as malleable-iron castings, it is essential, and any suggested improvement in the apparatus and process adopted is worthy of careful consideration. The illustrations Fig. 1 and 2 show a plan and a sectional elevation respectively of a furnace designed more particularly for malleable-iron castings. The claims made for the improvements incorporated in this design are many, and include:—

1. Reduction in time required to obtain the necessary temperature, and also in treating the castings. This

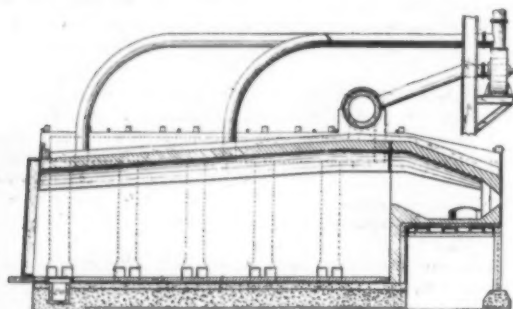


Fig. 2.

increases the capacity of the furnace, and reduces costs of operation.

2. Heat is controlled in an improved manner, to effect uniform and relatively quick treatment of castings in the annealing chamber.

3. The castings may be subjected to a non-oxidising atmosphere, reducing considerably the deterioration of the annealing pots.

4. Simplicity of construction and operation.

With these advantages in view, the process consists in supplying heat to a charged annealing chamber and simultaneously exhausting the products of combustion from a number of points along the lower portion of the chamber to raise the temperature to the desired degree, then reducing the heat supply to the chamber and the rate of exhaust from it to produce a soaking temperature, and subsequently slowly cooling the chamber.

Exhausting the products of combustion from the lower part of the chamber has the effect of facilitating the circulation of the heated gases over the articles being annealed, and by returning at a higher part of the chamber, as shown in Fig. 2, a non-oxidising atmosphere is produced. In order to obtain this result, the annealing chamber is connected at spaced points with a conduit system having power-operated fans for drawing products of combustion from one portion of the chamber, and discharging without admixture to another part.

A sectional-plan view of such a furnace is shown in Fig. 3, in which each heating chamber is constructed of suitable refractory material, the inner side walls of the two chambers being separated by a suitable insulation which allows for expansion. Extending from the end wall at an elevation above the bed is a base supported at its outer end by uprights. The base comprises longitudinal and transverse channels on which rests a fire-bed. Each of the annealing chambers and its fire-chamber are roofed with fire-brick, which is covered with a suitable insulation. The side walls and top of the fire-chamber converge, and at their outer portions these walls and the bed form an opening for a burner or other suitable means for supplying powdered coal under pressure. The end of the chamber opposite to the fire-chamber is open,

giving access for the annealing pots. The opening is closed by a door which is sealed when the furnace is in operation.

A main flue formed in the upper portion of each side wall and extending longitudinally from end to end, the side wall being thickened and extended upwards, above the top, provides the flue. The flues formed in each of the side walls connect at their upper ends with the adjacent main flue and lead downwards to the flooring, and each is connected with one or more exhaust ports leading through the side walls adjacent to the flooring. The manifold for conveying the gases may be suitably insulated on its inner surface to protect its metal shell. It is connected by conduits, with a main conduit which in turn is connected with the inlet of a suitable suction or exhaust mechanism, preferably comprising a casing and a fan mounted on a special bracket. The fan is connected to the shaft of a motor, and driven to exhaust the products of combustion and gases from the chambers.

Dampers, preferably independently operated, control the direction of the products of combustion and enable them to be returned to the chambers to effect a non-oxidising condition. Each vertical flue is provided with a damper which is suspended by a chain passing over sheaves and connected to a notched operating handle, the latter being held in any adjusted position by the engagement of the notches over the edge of an aperture in a vertical plate. As shown in Fig. 1, all the dampers of a chamber are independently operable from a single station. To prevent any air, which may enter through the charging door, from obtaining access to the working chamber, and also to ensure a sufficient supply of heating gases at this point, the flues adjacent the door are connected by a conduit arranged below the floor-level, and covered by a grating.

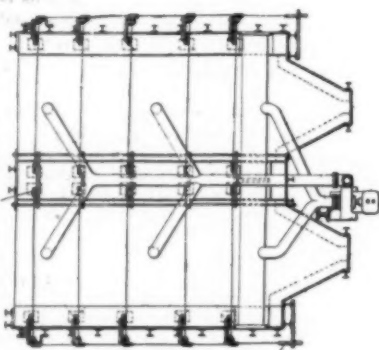


Fig. 1.

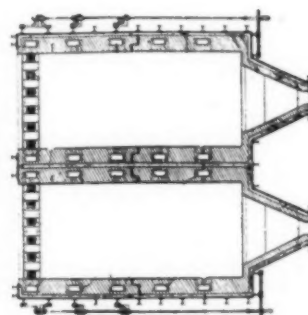


Fig. 2.

324,627. H.M. ROBERTSON, Century Building, Cleveland, Ohio, U.S.A. Patentees, Messrs. White, Langner, Stevens, Parry and Rollingson, Agents, Jessel Chambers, Chancery Lane, London, W.C. 2.

DRY PROCESSES OF REFINING METALS AND ALLOYS.

In a process for refining metals and alloys particularly iron and copper and their alloys, oxides and carbon are added to the molten bath in the proportions theoretically required to form carbon monoxide. An additional amount of an oxide of a metal of the bath may also be added. For example, an alloy consisting of 86% of copper, 5.9% of tin, 5% of zinc, 2.3% of lead, 0.4% of nickel, and 0.2% of iron may be treated by the addition first of 1.8% of zinc oxide, and then of 0.6% of a mixture of coal dust and zinc oxide in proportions to form carbon monoxide in the bath.

327,570. W. REITMEISTER, Kerchmöser, Havel, Germany, Patentee.

Business Notes and News

Human Aspect of Industry.

There is reason to believe we have come to the turning point in industry and invention, and that men of keenest intelligence and widest experience will find that the work worthy of their abilities lies in the neglected field of social organisation and control. Recognition of the human side is now being manifested in a new kindness in the promotion of which the Industrial Welfare Society has been very active. At this Society's conference recently the Duke of York urged the importance of the human side of industry in a very pointed message. Owing to world conditions, industry is faced with many problems which can be solved only if careful thought is given to new discoveries in the technical and managerial fields. It is in the latter direction that the Society can assist the directors of firms to bring their works into line with those where, by virtue of an enlightened labour policy, competition is being successfully met. "Unless employers are carrying their workpeople with them, removing causes of friction and misunderstanding, and creating new enthusiasms," said the Duke, "they cannot hope to prosper."

A very useful purpose will have been achieved by the conference if it has served to bring home the lesson that the human side of industry can no longer be ignored.

Improved Crane Equipment at Middlesbrough.

With a view to avoiding congestion and thus minimising delay at Middlesbrough dock, the London and North Eastern Railway Co. have prepared a scheme for improving the crane equipment. The company has obtained Government aid to carry out the scheme and the work is to be put in hand shortly. The facilities available for loading and discharging at the dock comprise 42 cranes, of these 39 are to be replaced by the latest type of electrically driven cranes. The new equipment will be specially designed to handle cargoes at a high speed in order to increase the facilities of the present dock and reduce the possibility of congestion. The cost of the scheme, it is stated, will be approximately £200,000.

German Economic Situation.

The economic and financial situation in Germany was discussed recently by Herr Dietrich, the Finance Minister, in the course of an electoral speech, in which he made a comparison between the difficulties confronting Germany and Great Britain. In commenting on the fact that these countries were suffering severely from unemployment, he said Germany differed from Great Britain in that their imports were at present less than exports; exports had grown since 1925 by more than 4,500,000,000 marks (£225,000,000), while imports had steadily declined. British exports were little higher than those of Germany—at the present they were even a little less,—but British imports amounted to nearly 9,000,000,000 marks (£450,000,000) more than the German totals.

Further, they had in Germany a much more even internal balance in that their own agriculture supplied the main needs of the population, and gave work to about 10,000,000 persons, whereas in Great Britain less than 2,000,000 were employed on the land. The internal exchange was, therefore, relatively to the population, much greater than in England, and this was his main reason in thinking that, with the continuance of ordered conditions, the German unemployment figures should not increase greatly above their present level (about 1,900,000 persons in receipt of relief in a population of about 63,000,000).

Coal Loading Plant to be Erected at York.

A mechanical coaling plant is about to be erected at the Clifton locomotive yard, York. While there are several mechanical plants for loading tenders at a number of locomotive centres, the new equipment at York is to embody many new features, and in consequence will be the latest of its kind in this country. It will be of 500-ton capacity, and is to be erected at the north end of the Clifton locomotive sidings. It will be operated electrically.

The equipment is to be fitted with an anti-coal breaker apparatus to reduce the breakage of coal which occurs on mechanical loading plants, and if this gives complete satisfaction there is every likelihood that other plants of a similar character will be erected elsewhere.

Motor Tankers for the Continent.

The shipbuilding firms in this country are naturally much concerned at the placing of orders on the Continent for nine motor tankers by the Standard Shipping Co., of New York, at prices much lower than were quoted in this country. In view of the general depression in trade and the amount of idle shipping available, the demand for ordinary cargo tramp vessels is almost negligible. It is to the construction of vessels designed for specialised trades that shipbuilders are naturally looking for supplying the winter's employment, and the loss of these vessels, which amounts to about 150,000 tons of prospective work, is rather a heavy blow to the shipbuilders of this country. The news that one of the shipbuilding yards of Messrs. Cammell Laird's at Birkenhead, and of Messrs. Harland and Wolff's at Belfast, are likely to close unless contracts are booked in the near future, indicates the depressed state of this important industry. The contract for these vessels, which has gone to the Continent, would have materially assisted the resuscitation of shipbuilding in this country, and caused a more optimistic spirit to assert itself in many centres.

Transporting Heavy Electrical Equipment.

The London and North Eastern Railway Co. have completed arrangements for the conveyance of 1,000 tons of electrical equipment from Newcastle-on-Tyne to Ymuiden, Holland. This equipment consists of two turbo-alternators, complete with condensing plant, which C. A. Parsons and Co., Ltd., have manufactured for the Provinciale Electriciteits-bedrijf Van Noord. The machinery is to be conveyed in three special trains from Newcastle-on-Tyne to Harwich, where the trucks will be shunted on to the train ferry and conveyed to Zeebrugge, and subsequently over the Belgian and Dutch railways to their destination, no reloading or transshipment being necessary. The first train, consisting of about forty wagons, is expected to leave Newcastle-on-Tyne about September 21, and will be followed by two 24-wagon trains in October and November; these last two trains will be loaded beyond the normal loading gauge, and will, therefore, be worked through to Harwich on a Sunday, when the adjacent lines can be kept clear. Two wagons will carry loads weighing 65 tons each, making 104 tons with the weight of the wagon. These will be the heaviest single truck loads that have ever shipped by the Harwich-Zeebrugge train ferry.

Cost of Smoke Pollution.

At the concluding session of the conference of Sanitary Engineers held at Ilfracombe, Mr. T. E. Birtwistle, speaking on the subject of smoke abatement, referred to the effect of smoke issuing from domestic chimneys and its influence on the respiratory organs. It is estimated that the amount of soot issuing from domestic chimneys is about five times that from industrial chimneys. In addition to this, domestic smoke is more serious in its effect, because it is a product of combustion at a lower temperature. Apart from the health of the community, it has been computed that the loss in assembled material as a result of smoke pollution amounted to £40,000,000 a year. He predicted the day would come when all coal would be carbonised before use.

There is no doubt the sulphur contamination of atmosphere is a big problem, whether from domestic or industrial chimneys, and low-temperature carbonisation would eliminate a considerable proportion of the sulphur, the gases and vapours evolved by carbonisation containing practically all the volatile sulphur, which could then be removed from the residual gas, after extraction of the low-temperature tar and the light oils, in a relatively easy manner; but much research work is still required to be done before all coal used can be treated in this way.

British-Africa Expedition Contemplated.

It is interesting to note that an expedition is being organised to show and demonstrate the value of British products. It will be led by Capt. Geoffrey Malins, O.B.E., F.R.G.S., and is being arranged to leave England at the end of this year, and on arrival on the Continent will travel across Europe to Stamboul, through Asia Minor and Palestine to Egypt, and from there down through the heart of Africa to Cape Colony. The journey of about 12,000 miles will be made with a convoy of British cars and a motor-cycle unit. On such a journey much depends upon the vehicles themselves, as well as their accessories and fittings, and no doubt only the best and most useful of these will be carried.

Some Contracts.

A moving pyramid of steel, 80 ft. high, designed to transport the largest airships from the mooring mast to the shed, is to be constructed by Vickers-Armstrong, Ltd., at their Elswick Works, Newcastle-on-Tyne. The structure is required for use at Cardington, and it is intended to commence work on it at once. It will be the first of its kind in Britain. Caterpillar movement is to be fitted at the base, and a winch will be used to adjust the height of the airship from the level of the mooring mast to the height of the airship shed. There is a similar but smaller transporter in Canada.

Messrs. C. A. Parsons and Co., Ltd., of Heaton, Newcastle, have secured the contract for making the turbine blades for the new Cunarder, to be built by John Brown and Co., Ltd., of Clydebank. It is stated that 50 tons of these blades will be required.

The Westinghouse Electric International Co. have secured an order for four passenger locomotives from the Chilian State Railways. They will represent a new type of electric locomotive, and will be of 130 tons, 3,000 volts, with a speed of 63 m.p.h.

Sir William Arrol and Co., of Glasgow, have been successful in securing the contract for the new bridge to be constructed across the Clyde. The Glasgow Corporation have been informed that a Government grant will be available for the scheme. It is expected that the work will commence almost immediately. The new bridge, which will be of the steel-girder type, will span the Clyde at James' Street, and will take the place of the present wooden structure. The work is to cost £116,614, of which amount the State will bear 60%. The Corporation, it is stated, have under consideration plans for the construction of a larger bridge over the Clyde, in the vicinity of the Glasgow harbour.

There is apparently a tendency to substitute motor buses for trams in many municipalities, and Wigan Town Council, who have decided to take this course, have accepted the tender of Leyland Motors, Ltd., for ten complete Titan double-deck buses and twenty chassis, at a total cost of approximately £35,480. Further orders for twenty motor bodies are being considered.

The contract for escalators in connection with the programme for the extension of the Piccadilly Tube and the reconstruction of certain stations in the Central area of London, has been placed with Waygood Otis, Ltd.; about fifty will be required, similar in design to those now in operation at numerous Tube stations. This is the largest contract of its kind that has been placed in this country.

Charles Brand and Son, civil engineering contractors, have been awarded the contract for the construction of the tunnel section of the Southgate extension of the Piccadilly Tube. The tunnel section extends from Finsbury Park northwards to Maidstone Road, Southgate, a distance of approximately $4\frac{1}{2}$ miles.

In connection with the electricity frequency change-over in the North-Eastern area, the Newcastle-on-Tyne Electrical Supply Co. have placed a contract for a power station at Dunston-on-Tyne with Messrs. McAlpine and Co., of Newcastle, the total cost of the work being £200,000. When the station is completed it is expected that the total cost of electrical developments at Dunston will be about £2,000,000. The erection of 1,400 steel towers to carry cables from Dunston in connection with the regional "grid" scheme will be necessary. This contract is in addition to two for electrical machinery placed on Tyneside recently at the total cost of £600,000. It is expected that the change-over will ultimately involve an expenditure of £10,000,000, most of which will be spent locally.

The Air Ministry and the War Office have ordered further six-wheeled vehicles from Crossley Motors, Ltd., Gorton. Sixty-three machines are to be supplied to the Air Ministry and fourteen to the War Office. These orders were obtained after strenuous comparative tests. The machines are of a special type, being constructed to operate over very rough country, and where ordinary vehicles would go out of action.

Further contracts, amounting to about £600,000, have been placed by the Central Electricity Board. These include a large contract for general cables in connection with the South-east England electricity scheme, placed with W. T. Henley's Telegraph Works Co., Ltd., London, a contract for general meters required for the Central England electricity scheme, placed with Messrs. Chamberlain and Hockham, Ltd., Birmingham.

Messrs. Hudswell, Clarke and Co., of Hunslet, have secured an order from the Peruvian Corporation for three locomotive boilers, together with locomotive spares.

The Glasgow Corporation have decided to expend £163,575 on 100 new buses to augment the present service of the city. The Glasgow firm of Cowieson and Co. is to supply the body-work of the vehicles at £690 each; Leyland Motors, Ltd., 75 chassis at £950 each; and the Vulcan Engineering Co., Ltd., 25 chassis at £933 each.

Another important contract in connection with the electricity grid scheme has been placed with Messrs. A. Reyrolle and Co., Ltd., of Hebburn-on-Tyne. This new contract is for 66,000-volt switch-gear of their patent metal-clad type for the North-East electricity scheme, and it is required for the sub-stations to be erected at Sunderland, South Shields, and Hebburn. The value of the contract is reported to be about £100,000.

The Egyptian State Railways, it is stated, have placed a contract with the Birmingham Railway Carriage and Wagon Co. for the supply of twenty 10-ton petroleum tank wagons at the price of £E329 per wagon.

Messrs. Swan, Hunter and Wigham Richardson, Ltd., Wallsend, have booked a contract for two large motor-tankers for Norwegian owners with engines from Wallsend Shipway and Engineering Company, Ltd. These are a welcome addition to the contract for the New Zealand floating dock, the order for which was received a few weeks ago. A further order for a passenger and cargo vessel has been booked for French owners.

An order for the latest automatic type of coal-washery plant capable of dealing with 250 tons of coal an hour in two units of 125 tons each, has been placed, by the Newport Abercarn Black Vein Steam Coal Company, with Nortons (Tividale), Ltd., of Tipton, Staffordshire.

An Induction Furnace for Non-Ferrous Work.

Many coreless induction furnaces are now in successful operation for steel melting, but it is of special interest to note that among equipments recently ordered from the Metropolitan Vickers Electrical Company is one for non-ferrous work. This order has been placed by Messrs. Hopkinsons, Ltd., of Huddersfield, the well-known makers of high-grade steam valves and boiler fittings. The equipment is to be installed in the firm's "Platnam" foundry, where special alloys are melted for this work.

The furnace to be supplied is of the Metropolitan Vickers standard type, and of $\frac{1}{2}$ -ton capacity, designed to melt its full charge in one hour from cold. The furnace proper is contained in a steel case, which is equipped with motor-driven tilting gear. The supply of power to the furnace is provided by means of a motor-generator set taking power from the mains at 440 volts, 3-phase, 50-cycles, and generating at 1,000 volts, single-phase, 500-cycles. The equipment will include condensers for power factor correction and equipment for automatic voltage control. This latter provision is of importance, in that it leaves the operator free to concentrate his attention on the metallurgical considerations of the work.

The service for which the furnace is required is an interesting example of the class of work for which this type of melting equipment is particularly suitable. The manufacture of metal parts, and especially valve seatings, for use under steam conditions of high temperature and pressure, requires exact control with regard to the materials and processes used. Compared with other types of melting equipment the coreless induction furnace possesses notable advantages in these respects. It gives accurate control over the melting process, and since it incurs neither appreciable loss in constituent materials nor addition of impurities, it makes possible exact control of the composition of the material produced.

IRON AND STEEL REPORT.

Now that the holiday season is at an end there is a quiet hope of better times for the iron and steel trades, without, however, any of the confident anticipation of more normal years of an autumn buying "push."

Already, in more than one centre, some slight improvement in conditions has been experienced in respect of foundry iron, the recently reduced prices of which have had a favourable influence. Users have displayed a somewhat freer disposition to enter the markets, and whilst so far the bulk of the business that has been placed has related to transactions extending over comparatively limited periods, some of the better-situated consuming firms have shown sufficient faith in the stability of the pig-iron market to cover themselves over the next two or three months. If anything aggregate deliveries of iron are rather heavier than during the past few months, and on balance there has been some measure of improvement in conditions at the foundries. There has been little in the way of price developments in respect of foundry iron during the past month, and the recent substantial cuts in both Cleveland and Midland brands may be regarded, from the point of view of users, as having brought values to a reasonable level.

Uncertain conditions prevail in finished iron. The substitution of steel for iron in many directions has, of course, dealt a permanent blow to the bar iron trade, though apart from this factor there is the ill-effect of the serious competition in some sections from Continental products to be taken into account, particularly in common bars.

Up to the present the bulk business in heavy steel has not participated in the slight improvement experienced by foundry iron, and the varying degrees of slackness at the consuming end—constructional engineers, shipbuilders, locomotive engineers, boiler-makers, textile machinists, and many branches of general engineering—continue to react not only on the volume of new business, but also on the rate at which steel is going into consumption against old contracts. The recent collapse of the Continental Steel cartel's selling arrangements, and the extraordinarily cheap prices at which imported finished and semi-finished products have since been offered in this country, have also had a potent influence on the market for British steel, consumers of which are showing a growing disposition to postpone fresh bulk buying until they see what develops in the way of price modifications, following upon the next meeting of steel producers. So much for the bulk trade.

In the case of special alloy steels, however, the last week or two has witnessed some improvement in the general situation. Not only have inquiries in this branch lately been of bigger volumes, but there has also been a noticeable expansion both in the number of actual orders and in the quantity covered by them.

One of the important features of the steel markets during the past month or so has been the weakness in Continental materials, a weakness which even the concerted attempts to control sales and prices have been unable to stem. The collapse during the past week or so of the central office for sales of imported steels in this country rapidly accentuated the downward movement of prices, which are now at levels that are proving attractive to users here. As examples of the quotations that are now ruling, the following for delivery in the Manchester district, for net cash against shipping documents, may be quoted: Sheet bars and billets at about £4 10s. per ton, Siemens' plates at round £7, Thomas plates at £6 5s., steel bars at about £5 7s. 6d., joists at £5 10s., sections at £6 7s. 6d., wire rods at £6 12s. 6d., and bar iron at round £5 7s. 6d. After a long period of marked indifference users here in a good many instances have entered the market and recent transactions, although only moderate in the aggregate, have been on a bigger scale than before.

NON-FERROUS METAL REPORT.

THE non-ferrous market has been influenced to some extent by the holiday spirit, and business has been somewhat quiet, although a little more activity has been noticeable during the last week. Apart from tin, which has made a moderate advance, the price movements in other metals indicate very little change. The market in Standard copper has been steady, and the recent small advance in price may be taken as a manifestation of a firmer tone. The Producers' Association for electrolytic copper remains unchanged, but selling in other directions continues at a slightly lower rate. Consumers' demands continue on a very restricted scale; they are either refraining from buying in the hope of forcing further reductions, or have sufficient on hand to meet immediate needs. Some consumers, it is stated, have taken advantage of the present low selling price to replenish stocks, but others, on the other hand, consider there is no immediate likelihood of electrolytic advancing in price, while there are possibilities of a reduction with a view to stimulating greater activity among buyers.

The market for tin has been somewhat irregular. The price fluctuated; easy conditions prevailing, the price receded, but subsequently buyers took more interest and supporting orders caused a sharp improvement, which, however, was not maintained. In spite of the reduction in production, the real necessity for a gradual advance in value is a general improvement in trade outlook, but there is every likelihood that the market will become firmer as the strengthening influence resulting from a restricted production becomes more widely appreciated.

After remaining steady for some time, the lead market has hardened a little, and prices have risen. The increase cannot, however, be regarded as representing any special demand of the consumers or any actual scarcity of the metal. The conditions remain practically the same as previously, and there is little of interest to report. Consumers continue to restrict purchases to their immediate needs. There is, apparently, a want of confidence, the view being held in some quarters that if the market was governed by normal economic conditions prices would be lower.

The spelter market has been irregular, but recently offerings have been more readily absorbed, and fairly heavy buying has been attracted, as a result of which there has been increased activity. Generally, while conditions leave ample room for improvement, there is a firmer tone, which indicates greater confidence in a recovery in price. It is considered that with the present low price, restricted production and the possibility of increased demand business should be stimulated and its recovery facilitated.

Although there is apparently no reason for optimism, the view is held by many that industrial prospects are a little brighter, and a slight improvement in business may be anticipated.

It is very probable that when an industrial improvement does manifest itself consumers who have been carrying on on a "hand-to-mouth" basis will be rushing for supplies, and as so many have become accustomed to stock on this basis there will be a period during which prices will soar until conditions readjust themselves.

Personal Notes.

Mr. Stanley C. Icke has been appointed Chairman of the Brooke Tool Manufacturing Company, Ltd., in succession to the late Mr. A. E. Owen. Mr. Icke has served the company in the position of managing director for the past twenty years.

Owing to ill-health, Mr. W. Lee Matthews has resigned the management of the London business of Thos. Bolton and Sons, Ltd., and Commander W. T. Bird has been appointed Sales Manager of the London district.

MARKET PRICES

ALUMINIUM.		GUN METAL.		SCRAP METAL.	
99% Purity	£95 0 0	Commercial Ingots	£71 0 0	Copper Clean	£42 0 0
Castings, 2.L5 Alloy	lb. 1/3-1/8	*Gunmetal Bars, Tank brand,		" Brazieri	39 0 0
" 2.L8	" 1/4-1/9	1 in. dia. and upwards.. lb.	0 1 0	" Wire	—
" Silicon	" —	*Cored Bars	0 1 2	Brass	31 0 0
ANTIMONY.		LEAD.		Gun Metal	42 0 0
English	£38 0 0	Soft Foreign	£18 5 0	Zinc	9 0 0
Chinese	27 0 0	English	19 10 0	Aluminium Cuttings	56 0 0
Crude	21 10 0			Lead	16 5 0
BRASS.		MANUFACTURED IRON.		Heavy Steel—	
Solid Drawn Tubes	lb. 10½d.	Scotland—		S. Wales	2 14 9
Brazed Tubes	lb. 12½d.	Crown Bars	£10 5 0	Scotland	2 13 6
Rods Drawn	" 10½d.	N.E. Coast—		Cleveland	2 7 6
Wire	" 8½d.	Rivets	11 10 0	Cast Iron—	
*Extruded Brass Bars	" 5½d.	Best Bars	11 5 0	Lancashire	2 12 6
COPPER.		Common Bars	10 15 0	S. Wales	2 15 0
Standard Cash	£47 7 6	Lancashire—		Cleveland	£2 15 0 to 2 17 6
Electrolytic	51 11 0	Crown Bars	10 5 0	Steel Turnings—	
Best Selected	50 0 0	Hoops	13 0 0	Cleveland	2 0 0
Tough	49 11 0	Midlands—		Lancashire	1 7 6
Sheets	79 0 0	Crown Bars	10 7 6	Cast Iron Borings—	
Wire Bars	52 2 6	Marked Bars	12 10 0	Cleveland	1 15 0
Ingots	52 2 6	Unmarked Bars	—	Scotland	1 11 9
Solid Drawn Tubes	lb. 11½d.	Nut and Bolt Bars	9 2 6		
Brazed Tubes	" 11½d.	Gas Strip	11 2 6		
FERRO ALLOYS.		S. Yorks.—			
†Tungsten Metal Powder ... lb.	£0 2 6	Best Bars	11 10 0		
†Ferro Tungsten	" 0 2 3	Hoops	12 0 0		
‡Ferro Chrome, 60-70% Chr.					
Basis 60% Chr. 2-ton					
lots or up.					
2-4% Carbon, scale 11/-					
per unit	ton 30 10 0				
4-6% Carbon, scale 7/-					
per unit	" 23 10 6				
6-8% Carbon, scale 7/-					
per unit	" 22 12 6				
8-10% Carbon, scale 7/-					
per unit	" 22 0 0				
‡Ferro Chrome, Specially Re-					
finned, broken in small					
pieces for Crucible Steel-					
work. Quantities of 1 ton					
or over. Basis 60% Ch.					
Guar. max. 2% Carbon,					
scale 10/- per unit....	" 33 10 0				
‡Guar. max. 1% Carbon,					
scale 13/6 per unit....	" 39 2 6				
‡Guar. max. 0.7% Carbon,					
scale 15/- per unit....	" 41 10 0				
‡Manganese Metal 96-98%					
Mn.	lb. 0 1 3				
‡Metallic Chromium	" 0 2 7				
‡Ferro-Vanadium 25-50% ..	" 0 12 9				
‡Spiegel, 18-20%	ton 7 5 0				
Ferro Silicon—					
Basis 10%, scale 3/-					
per unit	ton 5 17 6				
20/30% basis 25%, scale					
3/- per unit	" 7 17 6				
45/50% basis 45%, scale					
5/- per unit	" 11 10 0				
70/80% basis 75%, scale					
6/- per unit	" 18 10 0				
90/95% basis 90%, scale					
10/- per unit	" 25 6 0				
‡Silico Manganese 65/75%					
Mn., basis 65% Mn....	" 14 0 0				
‡Ferro-Carbon Titanium,					
15/18% Ti	lb. 0 0 6				
‡Ferro Phosphorus, 20-25%	ton 15 15 0				
FUELS.		SWEDISH CHARCOAL IRON			
Foundry Coke—		AND STEEL.			
S. Wales	£1 5 0 to £1 7 6	Pig Iron	£6 0 0 to £7 10 0		
Sheffield Export	0 17 0 " 0 18 6	Bars, hammered,			
Durham	0 15 0 to 0 15 6	basis	£17 10 0 " £18 10 0		
Furnace Coke—		Blooms	£10 0 0 " £12 0 0		
Sheffield Export	£0 17 0 to £0 18 6	Keg steel	£32 0 0 " £33 0 0		
S. Wales	0 17 0 to 1 1 6	Faggot steel	£20 0 0 " £24 0 0		
Durham	0 14 0 to 0 14 6	All per English ton, f.o.b. Gothenburg.			

* McKee Brothers, Ltd., quoted Sept. 8. † C. Clifford & Son, Ltd., quoted Sept. 8. ‡ Murex Limited, quoted Sept. 8.
 Lancashire Steel Corporation's Current Basis Prices:—Wrought Iron Bars, £10 5s. 0d.; Mild Steel Bars, £7 17s. 6d.; Wrought Iron
 Hoops, £12; Best Special Steel Baling Hoops, £9 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £9; C.R. & C.A.
 Steel Hoops, £12 10s. 0d. to £13 10s. 0d.; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted Sept. 8.

§ Prices quoted Sept. 8, ex warehouse.

